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# THE JOURNAL OF PROSTHETIC DENTISTRY

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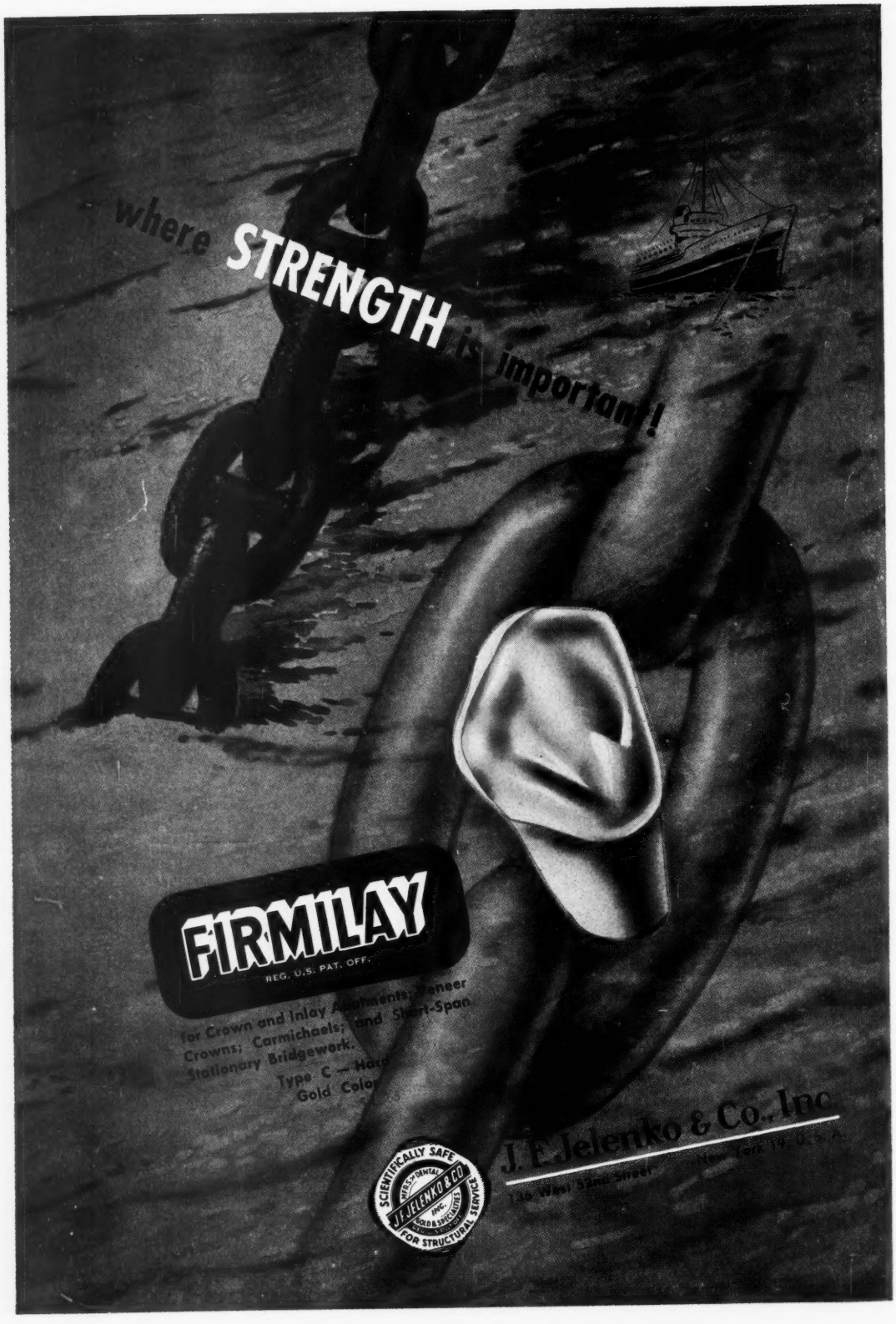


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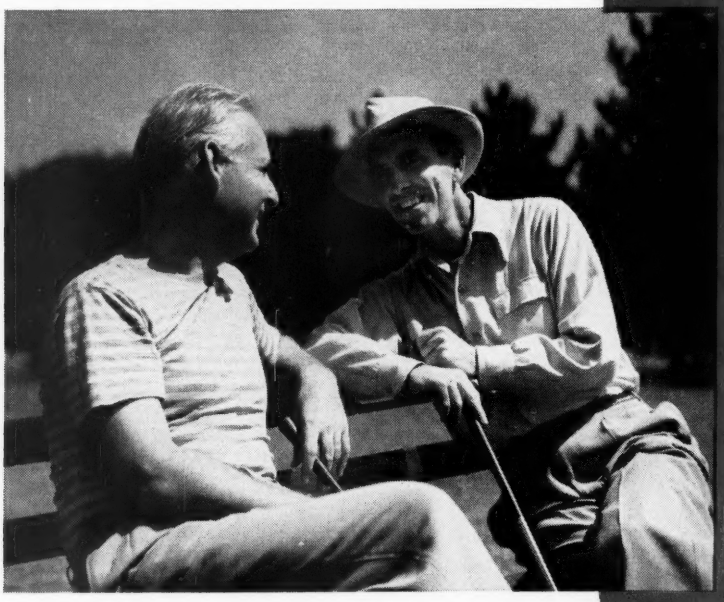

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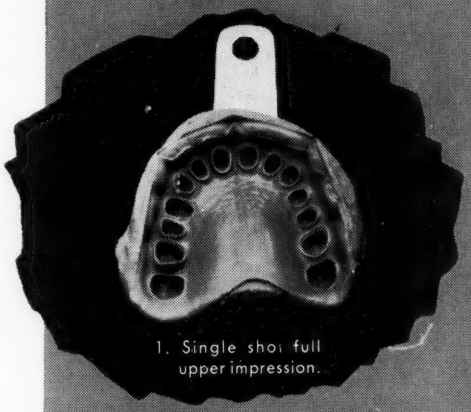

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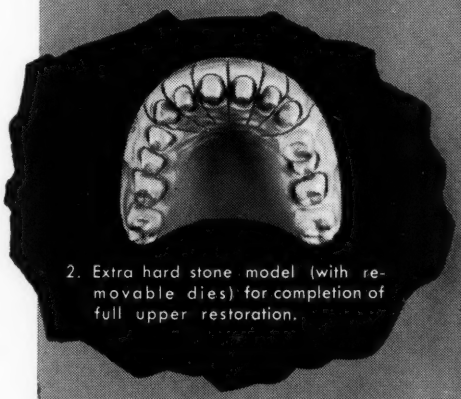

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## THROUGH THE EYES OF THE EDITOR

Ralph H. Boos discusses the importance of preparing and conditioning patients for denture service. This preparation includes the development of the proper attitude toward dentures as well as the elimination of conditions which lead to failures. His chief emphasis is upon techniques designed to make the oral tissues healthy before the impressions are made and to relax the musculature and other structures controlling maxillomandibular relations. The stretch-relax exercises have proved to be effective, but their effectiveness can be increased if the patient is required to keep the dentures out of the mouth in this preoperative period. Keeping the previous dentures out of the mouth for an adequate time prior to making impressions allows the tissues to be covered by the dentures to assume their normal healthy shape. In some instances, complete rest of these oral tissues for several days or weeks may be necessary in order to achieve the desired state of oral health.

Irving M. Sheppard reviews the various functions of the stomatognathic system as a background for his discussion of centric occlusion and centric relation. On this basis, he finds these terms inadequate for his needs and suggests the term "bracing position" to indicate the position of the condyles and mandible during function. This is a different approach to a complicated problem, and while it represents a relationship which is of extreme importance to the success of dentures, its accurate registration would seem to present some problems.

Harrison M. Berry, Jr. and F. Allan Hofmann describe a means for making cineradiographic observations of the movements of condyles in the glenoid fossae during mandibular function. The equipment permits the use of a minimum of exposure of the subject to radiation which is well within limits of safety. The automatic operation of the equipment tends to protect the investigators. The results as recorded on sound motion picture film provide valuable material for study. The plotting of the paths of arbitrary reference points from successive frames of the film seems to be an excellent means for following and visualizing the action. However, any conclusions that may be drawn from these plotted movements must be made after taking into consideration the relation of the path of the central rays to the condyle being photographed. The interpretation of individual records is subject to possible error because the image of the condyle may be lengthened or foreshortened according to the path of the central rays through it. This disadvantage does not decrease the value of the records provided this factor is recognized and compensation is made for it. The procedure provides a new approach to the study of mandibular movement.

G. A. Lammie, H. T. Perry, Jr., and B. D. Crumm discuss the neuromuscular aspects of their observations of a complete denture patient. The patient wore a series of six sets of test dentures made with occlusions built to conform to different vertical and horizontal maxillomandibular relations. As basis for this discussion, they give a simple description of the neurology and physiology involved.

Their suggestion of two "levels of function" provides a possible explanation for the ability of some patients to accommodate to errors in occlusion while others cannot do so. They recognize two horizontal positions at the level of vertical occlusal contact. These are the hinge position and the muscular position, and they suggest that occlusions should be built in one of these positions for some patients and in the other position for other patients. This brings up an interesting problem in diagnosis. They cite certain factors which would indicate the proper choice. There are others who seem to be thinking along the same line, but there are still others who recognize the variations but choose to make the dentures accommodate both positions, rather than to decide on one *or* the other.

Donald O. Lundquist reports on his studies of the activity of the buccinator muscle during function to determine its relationship to the retention of dentures. Electromyograms were made from control subjects with natural dentitions and from other subjects wearing complete maxillary dentures and removable mandibular partial dentures or complete maxillary and mandibular dentures. In the interpretation of the electromyograms, care was taken to avoid erroneous conclusions which might result from overlapping electrical fields. However, this is particularly difficult in the area studied because of the proximity of the masseter and external pterygoid muscles. Even though alterations of the buccal surfaces of the buccal flanges did not produce significant changes in the electromyograms, the "timing" of the contractions seems to indicate that the buccinator muscle plays an important part in the retention of dentures during function. It is possible, also, that this characteristic "timing" is a phase of neuromuscular control over the food being masticated. Further research on this problem is indicated, perhaps with buccal flange contours exaggerated in various directions.

Vincent R. Trapozzano reports on his tests of the relative efficiency of two types of teeth. Denture bases with interchangeable inserts carrying the various occlusal patterns were made for each of 8 patients. This procedure eliminated many variables. Data were recorded from chewing tests made with peanuts and carrots, from observations of the tissues made by 5 dentists, and from the comments by the patients. On the basis of these data, certain suggestions as to the characteristics which are desirable in posterior teeth are made. Much more research along these lines will be necessary before positive conclusions can be drawn about the selection of posterior tooth forms.

Dioracy Fonterrado Vieira reports his investigations of the factors which affect the setting of zinc oxide and eugenol impression pastes. The results should be of especial interest to those who use these materials, since the setting time is so closely related to the techniques for making impressions. There should be further research on these materials, and specifications similar to those for other dental materials should be established.

Harmon Shohet discusses the pains associated with pathologic temporomandibular joints. He points out the importance of an accurate diagnosis of the cause of the pain before treatment is instituted and suggests a sequence of treatment for each specific condition. To make his suggestions workable, he outlines a logical series of steps for handling patients with temporomandibular joint symptoms from the diagnosis to the completed treatment. A sound routine procedure can avoid difficulties for both the dentist and the patient.

Orland J. Caselli discusses the treatment of temporomandibular joint disturbances caused by chronic partial subluxation. He lists the causes and symptoms of this type of disturbance so it can be distinguished from others and relates these to the anatomy involved. He suggests the use of traction and reports a high percentage of success.

T. S. Malson describes his technique for reproducing the external contours of clinical crowns in gold restorations. This procedure will simplify one of the most difficult operations in connection with partial denture service. When decay occurs under a clasp of an otherwise useful partial denture, the restoration must not only fit the prepared tooth, but the external contour must be reproduced as well. This technique seems to solve this problem very well.

Thomas B. Sharp discusses the advantages of vacuum-fired porcelain crowns and inlays and lists situations where they are the restorations of choice. He describes his diagnostic procedures and his techniques for tooth prep-

aration, impressions, care of the prepared teeth, and the firing and cementation of these restorations. When this type of work is properly done, it results in satisfaction to both the patient and the dentist. The making of all-porcelain restorations should not become a lost art in dentistry.

Wilfred D. Whiteside suggests that Steele's interchangeable facings can be modified for lower anterior pontics so that they are strong, sanitary, and have satisfactory esthetics. The technique is simple and practical.

Herbert Swerdlow and Harold R. Stanley, Jr., report on their research on the reaction of the dental pulp to cavity preparations with high rotational speeds of the cutting instruments. They made histologic examinations of 53 sound human teeth which had had cervical cavities prepared by a carbide bur rotating at 150,000 r.p.m. The results indicated a mild traumatic injury which was reversible. The proximity of the preparation to the pulp seemed to be a factor as would be expected.

Edmund V. Street reports his evaluation of the use of ultrasonics in dentistry. He discusses the equipment and techniques critically and points out both the favorable and unfavorable features of ultrasonics as it is currently used. His suggestions for the improvement, care, and use of the equipment are good. On the basis of laboratory tests and two years' experience with ultrasonics, he classifies it as an adjunct to the dentist's armamentarium and reports it to be less effective than high-speed rotational instruments for certain operations.

Paul K. Hill discusses the present status of endodontics and points out a change of attitude on the part of the profession and great improvement in endodontic procedures. Its proper use makes possible the saving of many important teeth. However, if the procedures are not carried out with meticulous care, the results can be dangerous. Like other dental operations, endodontic treatment can be successful or unsuccessful according to the way in which it is done.

Ali Aram and J. Daniel Subtelny discuss the role of prosthetic "speech aids" for patients with cleft palates. They have made an extensive cephalometric study of the action of the pharyngeal tissues of cleft palate patients in different age groups. They point out a significant variation in the range of movement of these tissues according to age. There was a corresponding change in the site of pharyngeal closure. This is important because the obturating portion of the speech aid must be correctly located to be effective. They suggest the use of a type of appliance which makes use of this information.

Duni C. Miglani and Joe B. Drane discuss the treatment of deformities of the oral and facial structures by maxillofacial prosthesis. They cite various indications for this treatment and report on the frequency of need for this service. They describe and illustrate various types of appliances made in the course of treatment of different anatomic and physiologic defects. They emphasize the fact that any dentist who is interested enough in these unfortunate people can help them by applying the principles, materials, and techniques which are used in prosthodontics.

*—Carl O. Boucher*

## *COMPLETE DENTURES*

# PREPARATION AND CONDITIONING OF PATIENTS FOR PROSTHETIC TREATMENT

RALPH H. BOOS, D.D.S.
*Minneapolis, Minn.*

DENTAL TREATMENT INVOLVES THE TEETH, oral conditions, facial expression, head and neck musculature, temporomandibular joints, and a reference to the general systemic health and psychologic factors.

The patient who requires prosthetic treatment also requires treatment of possible malfunctions and pathologic tissue conditions. Preparation of the patient involves, not only the economic and psychologic factors, but also the physiologic factors related to the dental treatment. The conditioning of the oral tissues and the associated musculature may be considered as important as the technical procedure for a prosthetic service.

### EXAMINATION

The primary examination is made of the oral tissues and any prosthetic restorations which may be in use, or have been constructed for the patient. This examination is followed by a well-planned talk with the patient concerning his concept of dentistry, particularly in regard to his own experience. The discussion of any personalities is avoided. Many times the patient has definite concepts of dentistry which may affect the obtainable results. The patients may vary from the completely cooperative, tolerant patient to the opposite who considers dental restorations as foreign objects and will not adjust himself to the limitations of a prosthetic service.

The history of any previous prosthetic service should be recorded and understood before new treatment is started. A few questions regarding this history and the patient's viewpoint on prosthetics will provide information concerning the involvement of psychosomatics. The patient may place the emphasis on esthetics, masticating efficiency, or some other phase of the service and will desire a greater degree of satisfaction in that one part of the service. There should be an understanding of these individual desires and attitudes, as sometimes they are not attainable or conditions may be present which will preclude a successful result for

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that patient. The dentist will have a better understanding of his problems after a discussion, and the patient may appreciate the scope and limitations of the service. Many times, it would be better not to start the technical procedures until all of the conditions involved are completely understood.

The preparation of the patient also includes a careful examination and study of the anatomic structures related to the prosthetic service, such as oral structures, the musculature, and the temporomandibular joints. These anatomic structures may be affected by malfunction, pathology, allergy, diet, psychology, tissue displacement, and pressure. Any one or a number of these conditions may be present and be among the factors contributing to the need for a prosthetic treatment. Malfunction probably is encountered most frequently and may be caused by malocclusion, loss of teeth, and acquired conditions. Malfunction is prevalent also in many patients who require complete dentures. The musculature and the temporomandibular joints, as well as the masticatory functions, are affected by malfunction. To proceed with the technical steps of prosthetic construction without first correcting the abnormal conditions present may extend malfunction into the service and may result in a limited use or failure of the restorations.

The preparatory treatment and the conditioning of the anatomic structures should be the first procedure in prosthetic treatment. One of the most important structures involved is the musculature, as it is a predominant factor in mandibular position, esthetics, and masticatory efficiency. The mandibular position determines the position of the condyles in the glenoid fossae. When the musculature is normal and the tooth occlusion is in harmony with the movements of the mandible, the temporomandibular joint will usually be in normal function. All of these structures are interdependent.

## MUSCLE THERAPY

As the muscles are a predominant factor and may be returned to a normal condition more readily than other structures, the primary treatment is directed toward them. The conditioning treatment for muscles involves the application of physical muscular therapy directed particularly to the muscles of mastication. An exercise based on the stretch-relax theory is applied to these muscles. The complete exercise for the head and neck musculature is one that requires the patient to make a series of movements of the mandible while holding the head in a normal upright position. During instruction, the patient is seated in the dental chair in an upright position with the back and the neck supported by the chair. The arms are on the arm rests, and the feet are on the foot rest. The legs are not crossed because this would change the skeletal position. The patient is instructed to be relaxed and unstrained in this seated position. If any prosthetic restoration is present which causes an interference of movement or contact, it should be removed. Instructions are given to move the jaw to provide a stretch-relax procedure (Fig. 1).

First, the patient opens wide for about one-half a minute and then relaxes, permitting the mandible to come to rest position. No attempt is made to position the jaw. The patient relaxes, and the jaw is allowed to return to a rest position. The teeth should not come in contact, so there will not be any guidance from the

existing occlusion. The lips may or may not be together, depending upon the patient's normal relaxed facial expression. Next, the jaw is moved to the right as far as possible in a slow continuous stretch and then dropped back to rest position. The jaw should not be opened to an extreme position but only open enough to avoid tooth contacts. The jaw is then moved to the left as far as possible and back to rest; then forward and back to rest; then retruded and back to rest; and finally open and back to rest.

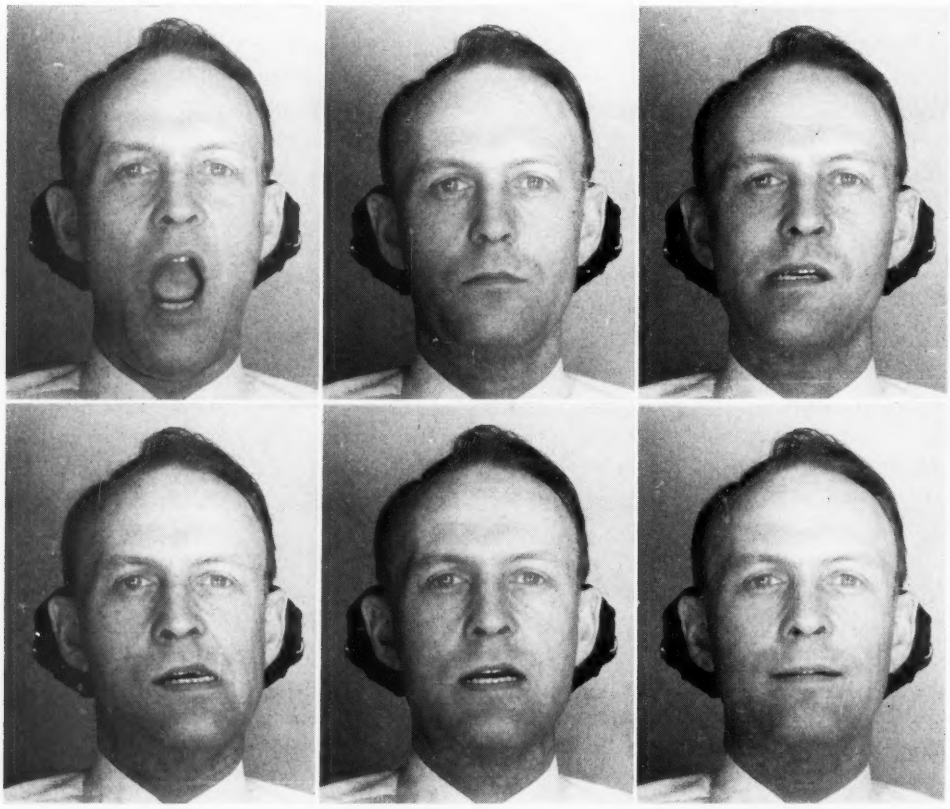

Fig. 1.—Mandibular muscle therapy in the form of stretch-relax exercises is used to condition the muscles. The jaw is opened and returned to rest, moved to the left and returned to rest, moved to the right and returned to rest, moved forward and returned to rest, moved back and returned to rest, and opened and returned to rest.

The mandible has been moved in every direction so that all muscles attached between the mandible and the skull have been stretched and relaxed. The wide-open position and back to rest, as well as the forward position and back to rest, will often be most effective in bringing about a normal unstrained mandibular position. The patient is instructed to allow the jaw to be at rest without tooth contact. All patients, except those whose existing restorations have been constructed with an excessive occlusal vertical dimension, will exhibit a free-way space (inter-occlusal distance) which provides a freedom of the occlusion from stress.

This exercise may be given as a prescription, requiring the patient to follow the prescribed movements for 2 or 3 minutes four times a day. The most convenient times would be in the morning after arising, about 10 o'clock, about 3 o'clock in the afternoon, and upon retiring. The patient's exercises should be evaluated when the instructions are given as some may exercise too vigorously and some not enough. Your instruction should indicate the desired amount of effort. If pain is a factor in the exercise, the pain can be reduced by sedation and hot packs.

The muscles must be stretched and relaxed if they are to return to a more normal condition. Sometimes, it is necessary to proceed very slowly with modified movement before the desired results are obtained. The patient should always be cognizant of maintaining a space between the teeth and avoiding biting habits. Whenever the patient finds himself biting or clenching his teeth, he should open his mouth and stretch the muscles a little, returning to rest to relieve the tension.

The exercise is in no sense a method designed to develop muscle power. It is a procedure that enables the patient to relieve tension and learn relaxation. Exercises such as chewing gum should be avoided, as they develop stress on the occlusion and require muscle power. The exercise is helpful not only for conditioning the muscles, but also in facilitating the movements required for many types of jaw relation registrations.

Every patient requires conditioning of the musculature and supporting tissue, even if all conditions appear to be normal. At the time the denture service is contracted, the patient should be put on the relaxation exercise. This will allow a minimum of a week to 10 days of conditioning before jaw relations are registered. The longer the time, the better the advantage in obtaining and facilitating normal registrations.

This exercise is a primary treatment for temporomandibular joint pain, bruxism, and malfunction. It permits the musculature of the mandible to relax and reduces the stress on the anatomic structures in the temporomandibular joints and on the occlusion.

## TISSUE CONDITIONING

Tissue displacement and pressure are present in varying degrees in every case in which a complete or removable partial denture base is being worn. Oral tissue is movable and displaceable. The amount of displacement varies with the individual tolerance of the patient and habits which may or may not cause abnormal pressure. If a prosthetic restoration is removed from the mouth and an impression is made immediately, there will be indications of displaced tissue in the impression (Fig. 2). The history of many denture patients includes a succession of dentures constructed on displaced tissue. As each denture or reline has been constructed, the old denture has been removed, and the impressions were made of the tissue in its displaced condition. Under certain conditions, this may result in an extreme accumulation of displacement with varying degrees of recession, plus possible nerve pressure as evidenced by sensitive areas and a burning sensation under the dentures. The rugae and the incisive papilla may be observed to be greatly displaced on some mouths. The incisive papilla covers the nasopalatine (incisive) foramen

through which nerves and blood vessels pass. Sometimes, the evidence of relief chambers and displaced soft tissue areas will be obvious in the palate. These conditions may be treated by conditioning these tissues and by using a nondisplacement impression procedure in the denture construction.

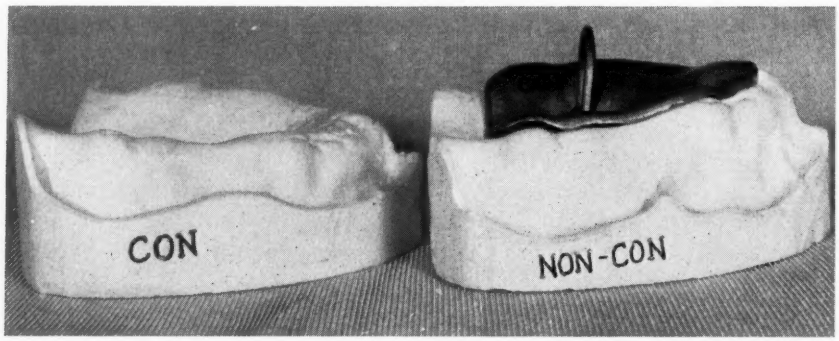


Fig. 2.—A metal matrix constructed on a cast made after the tissue has been conditioned will not fit on a cast of the same mouth made before tissue conditioning.

To condition the tissue, the patient should refrain from wearing the existing dentures for an absolute minimum of 12 to 14 hours before the impression for the new denture is made. This same period of rest is the minimum necessary before reline impressions are made. Every patient is able to be without dentures at least over night. The patient should leave any existing prosthetic restoration out of the mouth as much as possible prior to the making of the final impression. It should be left out every night and any periods possible during the day. The time should be extended to 24 to 48 hours or many days in instances where malfunction, inflamed areas, or burning sensation are noted. The length of time that dentures should be kept out of the mouth depends upon the appearance and condition of the tissue to be covered by the denture. Sometimes temporary relines are indicated for the correction of gross tissue changes.

From the day that the prosthetic service is contracted, the patient should be placed on a routine of cleansing and stimulating the oral tissues by washing them with cotton balls or a soft toothbrush and a normal saline solution or a mouth wash. A saline gargle should be used three or four times a day. The existing dentures should be cleansed carefully several times during the day if they are worn during this period.

The circulation of blood in the tissues of the oral cavity may be increased by proper exercise. This exercise consists of deep inhalation, closing the throat to prevent exhalation, and then forcing down on the diaphragm. This procedure will raise the blood pressure in the body and increase relief and circulation in the denture regions. This exercise may be done three times a day and just previous to making the final impressions.

## DIET

The tone and tolerance limits of tissue may be affected by the diet and the systemic condition of the patient. A discussion of his general diet, and a report

on a 7- to 10-day intake of food will indicate any unusual dietary habits. A well-balanced diet of natural foods is basically important. A supplement of organic vitamins and/or a therapeutic dosage of vitamins B and C will be an important aid for some patients. Riboflavin deficiency and cheilosis are observed often as fissures or cracking at the corners of the mouth. This usually indicates that a treatment of riboflavin and the B complex and C vitamins is necessary. There are many other infectious diseases of the mouth which may be observed and referred for proper treatment. The presence of an extreme substandard tissue and osseous structure should be investigated further with a medical consultation.

### PATHOLOGY

Pathology of oral structures should be noted carefully by clinical observation and roentgenography. Leukoplakia or other precancerous or suspected cancerous lesions, or any questionable conditions, should be examined by biopsy and referred for treatment as indicated. Roentgenography of edentulous patients will aid greatly in the examination for anomalies, remaining teeth, roots of teeth, and cysts or tumors.

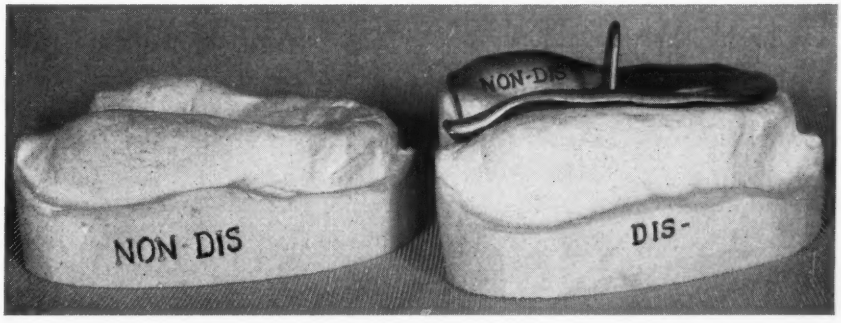


Fig. 3.—A metal matrix constructed on a cast with no tissue displacement will not fit on the cast of the same mouth when the tissue is displaced.

### ALLERGIC CONDITIONS

Allergy to denture materials is a possibility, although, fortunately, the percentage of occurrence is extremely small in comparison with the number of dentures constructed. The affected areas may produce burning sensations attributed to an allergy when the real cause is the displacement of tissue, pressure on nerve endings, malfunction, or general systemic conditions. The majority of allergies attributed to denture-base materials are due to these other causes.

A true allergy may be present when *all* of the tissue in contact with the denture-base material becomes irritated and inflamed. This irritation and inflammation would improve if the denture is removed, and when the denture is returned to the mouth, the irritation would reappear. The function of the denture should be nearly normal if malfunction is to be eliminated as a possible cause. The vertical dimension and the centric occlusion should be in harmony with the centric relation, and the adaptation of the denture base to the supporting tissue should be

good. Inferior materials and improper processing may be the cause of the suspected allergy. Some patients may be allergic to certain chemical components of the denture base. The treatment for these true allergic reactions is experimentation with other base materials, such as a change from the copolymer methacrylate resins to a vinyl resin or to a styrene resin. The most inert material possible would be a metal alloy that can be used in surgery.

The advantages of preparing and conditioning the patient may be extended to the technical procedures by following principles which aid in *maintaining* normal conditions (Fig. 3). At the present time, a nondisplacement type of impression procedure seems to meet these requirements because it provides a better tissue tolerance to biting forces.

## SUMMARY

The preparation and the conditioning of the patient should be the first procedure of prosthetic treatment. The procedure includes: (1) the establishment of a proper concept of prosthetic service in the mind of the patient and the development of a proper psychologic attitude toward this service, (2) thorough examination of the oral conditions and roentgenographs, (3) muscle therapy which includes an exercise prescription, (4) removing any prosthetic appliance from the mouth for a minimum of 14 hours before impressions are made, (5) tissue stimulation and cleansing, (6) removing and cleansing the existing dentures, (7) temporary relines, and (8) vitamin therapy, general diet, and proper consideration of general systemic conditions.

## CONCLUSION

Preparation and conditioning of patients increases the scope and adequacy of treatment and the results of a prosthetic service. It also provides the important direction of the patient's viewpoint in regard to the prosthetic service and improves the body conditions which are involved.

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808 Nicollet Ave.
Minneapolis 40, Minn.

# THE BRACING POSITION, CENTRIC OCCLUSION, AND CENTRIC RELATION

IRVING M. SHEPPARD, D.M.D.*
*Dental and Radiology Departments, Montefiore Hospital, New York, N. Y.*

CENTRIC OCCLUSION AND ITS COEXISTENCE with centric relation is generally considered the basic starting point of occlusal relationships.[1,2] The importance of these relationships to dentistry is apparent. Many of the methods of obtaining them, from jaw jiggling to complex recording techniques have been shown, however, to cause aberrant muscle and joint behavior.[3,4] Further doubts arise when the terminology is questioned. Presumably, centric occlusion is the junction of the sliding movements in lateral and protrusive directions, yet these are not movements used in mastication, speech, or deglutition.[5,6] A discussion of this subject from a physiologic viewpoint may be fruitful.

"Centric occlusion" implies the presence of teeth and, hence, as such cannot be properly applied to the edentulous infant, nor to the adult functioning without teeth, nor satisfactorily to the extreme "open bites" where few teeth occlude. "Centric relation" involves a condylar relationship of a retruded nature. This is delusive indeed when we consider that patients without condyles can and do have functioning occlusions.[7-9] It is further questionable when we consider the possibility of an unequal or an excessive retrusion resulting from the manipulation frequently employed to attain such retrusion. Unequal posterior displacement of the condyles or posterosuperior displacement is associated with joint symptoms, and so presents a hazard to such emphasis on retrusion.[4]

The assumption that closure in "centric relation" involves rotation of the mandible around an axis drawn through both condyles is also doubtful. Serial roentgenography and cinefluorography show that condylar movements are essentially translatory and do not ordinarily show hinge movement exclusively, except in cases of joint or muscle pathology.[4,10,11] Manipulation of the patient's mandible, training, the use of clutches and attached face-bows, employed to obtain hinge action, do not simulate normal functional movements but imitate those associated with pathology.[4] The dictatorship of the condyles, which the centric occlusion-centric relation theories imply, is negated by lack of evidence. It is furthermore doubtful, from a physiologic viewpoint, that a bone or joint will normally dictate movement. The known versatility of condylar movement and positioning is not in agreement with the theory of a micrometric axis of rotation that remains constant throughout life.[4,10,12,13]

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*Associate Attending Oral Surgeon.

In view of the implication that "centric" is not adequately descriptive, that centric occlusion is hardly applicable to the many patients without teeth, or those with teeth who have nonocclusion of many opposing teeth (open bites), and that domination of the condyles over occlusion is implied by "centric relation," it would seem proper to review some of the functions of the stomatognathic system to arrive at a suitable definition.

## MASTICATION

Mastication, the function for which many occlusions are equilibrated, seems too often confused with an imaginary lateral, grinding type of pulverization, a state which the bolus need not and rarely does attain before swallowing.[14,15] The requirements of preparation for swallowing seem to be that the bolus be small, smooth, and moist enough to be propelled down the pharynx (Fig. 1). Much of our prepared food, in addition to naturally liquid ones, is already in this state and forceful mastication is virtually unnecessary. With the more solid foods, proprioception prevents clashing of the teeth and jaws against each other so that excursive occlusal contact in mastication is rare, light, and fleeting in nature.[5] In any event, the time spent in eating is obviously a very small part of one's daily oral activity.

If mastication is so infrequently necessary in our present-day diet, and evidence indicates that when it does occur it is hardly in any of the excursive movements of of the mandible, our preoccupation with occlusal contacts in these excursions may well be unnecessary. Furthermore, the pulverization, which such masticatory movements would accomplish if they did occur, is unnecessary for digestion or nutrition.[14] The wisdom of introducing pathways for masticatory movements, which do not occur in mastication, and of governing them with abnormal condylar movement from a potentially hazardous condyle position, is questionable.

## DEGLUTITION

It has been shown that the most frequently occurring power closure of the jaws is in swallowing. Apparently, the mobile mandible braces itself against the immovable maxillae so that the tongue may propel the semisolid bolus into the esophagus (Fig. 2). The relatively loose mandible would be subject to movement in a direction opposite to the propulsive thrust of the bolus, if it is not braced in some way against the maxillae. An example would be the free-floating fireboat which cannot propel streams in one direction without movement in the opposite direction. Newton's third law requires playing streams in opposite directions to avoid movement of the boat. The neuromuscular mechanism apparently seeks a bracing position whatever the degree of vertical opening may be, though it may in some instances, because of obstacles such as malposed teeth, require protrusion or rotation of the mandible to achieve it. The adaptability of the musculature here, as in the rest of the body, is considerable, as perhaps evidenced by the maxillomandibular contortions that are encountered clinically without muscle pathology. Hard tissues, such as those in the temporomandibular joints, may not survive contorted jaw relationships without symptoms, such as clicking or pain; nor the

Fig. 1.

Fig. 2.

Fig. 1.—The bolus is about to be propelled into the esophagus.
Fig. 2.—The teeth and jaws are in the bracing position during the extremely rapid propulsion of the bolus.

teeth and alveolar bone without periodontal destruction. However, the musculature seems to continue adjusting to such trying situations, relatively seldom going into spasm or fibrosis.

The adaptive nature of the musculature in achieving a bracing position is further illustrated by the interposition of the tongue between the upper and lower jaws in edentulous infants and adults. Inasmuch as this type of bracing is apparently not a power closure, it does not lend itself to the propulsive thrust, posteriorly, of the tongue, which seems necessary for the more solid types of food. It may be remembered that swallowing is a survival mechanism and, as such, it is understandable that the muscles will do everything possible to achieve it.

It seems evident that the bracing position is a most important one (Fig. 3). While this same position has often been described as centric, centric occlusion, and functional centric, we can realize that there is, certainly at times, nothing "centric" or "occlusal" about it. These terms are applicable only where teeth are present. The further elaboration that centric occlusion must coincide with centric relation involves the very questionable condyle positioning already discussed. The bracing position, by contrast, describes the function of this position and is applicable to all ages and occlusal conditions, regardless of the presence or absence or positioning of the teeth or condyles. It describes the function of this position of the mandible and implies activity of the neuromuscular mechanism, certainly a major factor in occlusion. Its more universal application may be further illustrated in patients without condyles, with fractured condyles healed in malposition, and in patients with hemimandibulectomies.

## THE BRACING POSITION AND THE TEMPOROMANDIBULAR JOINT

The latitude in condyle positioning for the bracing position (Fig. 4), without joint symptoms, appears to be considerable, provided that both condyles are similarly placed on both sides, preferably not in an extreme posterior superior direction. It is thus apparent that the temporomandibular joints can accommodate many variations of bracing positions if the mandible is not rotated mediolaterally or unduly displaced in a posterior superior direction. In any event, the condyles do not dictate the bracing position, and certainly cannot, if they have been removed. Bracing occurs with good oral function despite the absence of condyles or the presence of malposed-malunited condyles in cases of bilateral condylar fractures (Fig. 5).

## THE MUSCULATURE

The adaptive capacity of the muscles of the stomatognathic system is considerable for most of the muscles, particularly in a vertical direction. This is apparent in complete denture prosthesis. The adaptability in a lateral direction is markedly less.[16] Yet the musculature will seek out a position of maximum bracing contacts and adapt to it. The sensitivity and learning capacity of this tissue, while not limitless, is considerable compared to the harder structures with which we are concerned, such as teeth and bone. In the absence of electromyographic equipment, which would indicate unequal muscle action, we must, therefore, give the

Fig. 3.—The bracing position with complete dentures.

Fig. 4.—The condyle is at the eminentia at the start of the masticatory stroke.

hard structures, namely the teeth and joints, preferential positions because of their lesser range of adjustability, in the order named, and rely on the far greater adaptability of the normal neuromuscular mechanism. The presence of muscular spasm or fibrosis may jeopardize any decision as to tooth or jaw relationship.

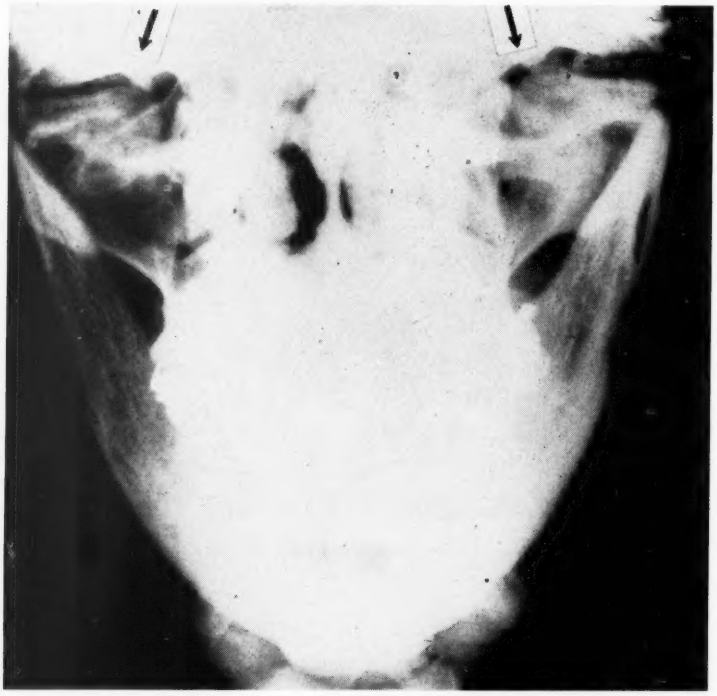

Fig. 5.—Bilateral condylar fractures with the condyles displaced medially and horizontally. Excellent function existed.

## TEETH, ALVEOLAR BONE, AND THE BRACING POSITION

Inasmuch as the bracing position is the most important meeting of the teeth of the opposing jaws from a viewpoint of frequency and force, it is well to examine this meeting in detail. We must bear in mind that neither a complete dentition, nor any teeth at all, are necessary for bracing. It is possible for such bracing to take place in areas of nonocclusion of opposing teeth as exemplified by "open bites," where the tongue is interposed. Whether teeth are in occlusion or not, the resultant forces exerted upon them in the bracing position should be in the long axes of the teeth. If they are not, migration, tilting of teeth, and/or periodontal disease may occur. Resultant forces frequently impel teeth lingually, buccally, mesially, or distally with each closure in the bracing position, and immediately following release from this position are directed in another, frequently opposite direction by the tongue or external musculature. In such instances, the teeth, if upright and repeatedly subjected to these alternately multidirectional forces, appear prone to bone loss and pocket formation. If they do not remain upright, some common

findings are: lingually tilted lower molars where the force in the bracing position is exerted upon the buccal surfaces of the lower buccal cusps (Fig. 6); upper molars tilted or moved buccally with widening of the arch in this area; and a history of opening of proximal contacts. In the latter instance, the forces in the bracing position are exerted against the palatal surfaces of the palatal cusps (Fig. 7). In the more pronounced examples of these findings, no occlusal tooth surface contact whatever may occur. Apart from the destruction to the periodontal tissues eventually caused by constant repetition of these alternating angular forces, the loss of vertical height caused by the tilting of the teeth promotes a more forward closure of the mandible for bracing. The approximately V-shaped lower arch then presents a wider arch to the fixed upper one. Opposing anterior teeth may, in such instances, be found with increased surface contact while lower posterior buccal surfaces and upper posterior palatal surfaces may increase in contacting area.

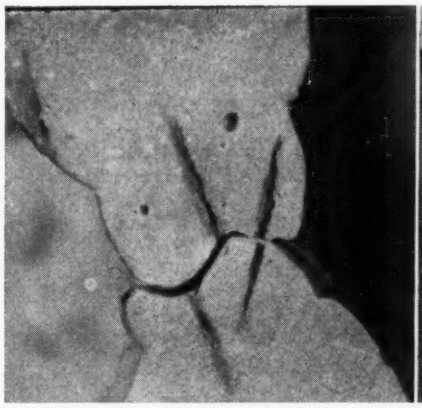

Fig. 6.

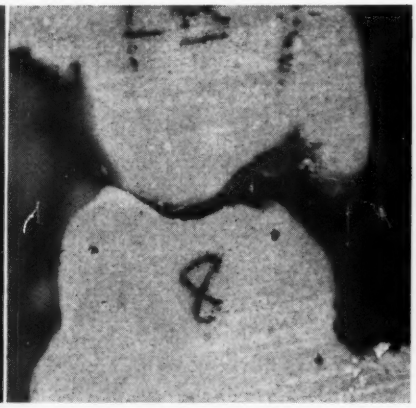

Fig. 7.

Fig. 6.—A nonocclusal contact of a lower tooth in the bracing position indicating the nonaxial force on the buccal surface of the lower buccal cusp.

Fig. 7.—A nonocclusal contact of an upper tooth indicating the nonaxial force on the palatal surface of the palatal cusp.

It seems apparent that the application of deleterious, nonaxial forces to the teeth, particularly when of an alternating character, is an important cause of periodontal destruction (Fig. 8). While the teeth have some capacity to adjust to these forces, as evidenced in elderly patients with worn dentitions, it appears minimal with soft diets commonly in vogue. Such adjustment by wear is further jeopardized by repair and replacement of worn or lost surfaces by extremely hard golds, chrome alloys, and porcelain. It should be remembered that nonaxial resultant forces can occur without contact of opposing teeth as evidenced by the atypical swallowers.[17] A factor in the formation of infrabony pockets may be the action of alternating multidirectional forces upon teeth between dense plates of buccal and lingual bone. The loosely trabeculated bone may resorb between these plates in response to alternating nonaxial stresses.

BRUXISM AND THE BRACING POSITION

The psychogenic factors at work in the promotion of bruxism are often evident and understandable. There are, however, limitations to which dentistry can go in psychotherapeutic treatment. If local inciting factors are present, it would logically be more within our province to remove them.

The contention of Jankelson* that bruxism is caused by tight confinement of cusps, inciting a struggling movement, may be an important factor. Clinical experience seems to indicate a lessening of this habit when bruxism facets are removed. We must also consider the possibility of the need for the masticatory musculature to perform some activity despite the softness and liquid nature of our diet.

Fig. 8.

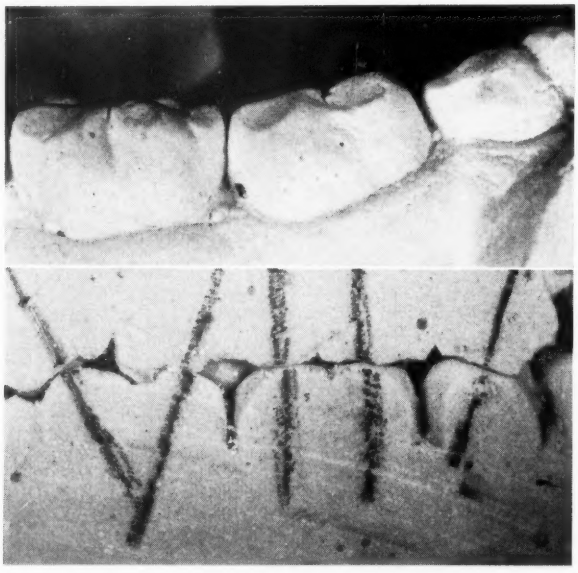

Fig. 9.

Fig. 8.—Facets on the buccal surfaces of lower teeth indicating nonaxial stress.
Fig. 9.—Casts sectioned in the bracing position indicating nonaxial stresses in a mesiodistal direction.

Another local factor in encouraging bruxism may be the approach of the cusps or teeth of the mandible to the bracing position. For the many and varied types of strokes involved in mastication, depending on the condition of the bolus with each stroke, it appears that the lower cusps should be free to enter the bracing position from any direction. The extreme opposite situation may be found in complete dentures where one denture has porcelain teeth, and the opposing one has acrylic resin posterior teeth which have had self-curing acrylic resin added to the occlusal surfaces and allowed to harden in the bracing position. The complete absence of freedom to close from varied directions in such an instance is an exaggeration of what may be found in deep-cusped natural dentitions. However, the

*Personal communication.

struggle for freedom of approach to the bracing position can thus, perhaps, be visualized. The presence of nonaxial forces during this process, abetted by failure of the confining surfaces to wear due to soft diets and extremely hard restorative materials, may result in periodontal pathology (Fig. 9). If the assumption that some bruxism is a struggle for freedom of function, then it cannot readily be termed a pathologic habit. Failure to achieve complete freedom by wear with nonaxial stresses resulting may be the cause of pathology, not necessarily the habit itself.

## CLENCHING AND THE BRACING POSITION

Clenching, unlike bruxism, may be completely of psychogenic origin in the natural dentition. While it is a convenient means of releasing tensions and satisfying a desire to punish oneself, the possibility of destroying oral structures in the process indicates its importance. It is significant that it usually takes place in the bracing position. If only axial forces are exerted upon the teeth, little damage to surrounding structures apparently occurs unless the pressures are extreme, frequent, and prolonged.

## SUMMARY AND CONCLUSIONS

It appears that the bracing position is the most important approximation of the maxillae and mandible from a viewpoint of frequency, force, and its role as a survival mechanism. In view of the evidence that the condyles do not dominate this meeting, nor are necessary for it, the term centric relation appears superfluous and potentially misleading with its emphasis on retrusion. The term centric occlusion appears inadequate for the approximation of the mandible to the maxillae where few or no teeth are present, or in the occlusion as the edentulous infants, children with erupting teeth, "open bite" cases, and edentulous adults. The term *bracing position* is proposed to describe more adequately this meeting of the jaws, its function, and to imply its domination by the neuromuscular mechanism.

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5 East 57th St.
New York 22, N. Y.

# CINERADIOGRAPHIC OBSERVATIONS OF TEMPOROMANDIBULAR JOINT FUNCTION

HARRISON M. BERRY, JR., D.D.S., M.Sc.,* AND F. ALLAN HOFMANN**
*University of Pennsylvania, School of Dentistry, Philadelphia, and Lancaster Cleft Palate Clinic, Lancaster, Pa.*

MOTION PICTURES MADE BY photographing the x-ray image on a fluorescent screen are known as direct cinefluorography. This method has contributed important information on joint function. However, its full exploitation has been prevented by the danger of excessive radiation to the patient because of the fact that high levels of radiation are required to create fluorescent screen brightness of sufficient intensity to register on the motion picture film. A new means of producing roentgen motion pictures of the joint in function is that of photographing an electronically intensified image. This method is known as indirect cinefluorography or cineradiography.

## IMAGE INTENSIFIER (AMPLIFIER)—CINERADIOGRAPHIC UNIT

The patient is seated between the x-ray tube and the image intensifying tube. The head is held rigidly in a head positioner adjusted so that the central ray passes through the condyle being examined and strikes the center of the 5 inch receiving screen of the intensifying tube (Fig. 1). This fluorescent screen emits visible light which causes an inner photocathode layer to give off an electron pattern of the image. These ejected electrons are accelerated by the 25 kilovolt tube potential and are concentrated by electrostatic focusing to a 0.5 inch diameter. Here the electron pattern impinges upon the phosphor layer of the viewing screen which recreates a visible image 1,000 times brighter than that originally produced on the receiving screen. Thus, image brightness of sufficient intensity to expose motion picture film is achieved by electronic means rather than by radiation; and hazard to the patient is reduced.[1-3]

The operator, wearing a leaded apron and a radiation film badge, stands behind a lead screen and views the image through an optically-ground lead disk over the viewing screen. When the correct patient position has been attained, a Polaroid-Land Camera is locked over the eyepiece and an exposure is made. One minute

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The cinefluorographic unit described was made available to the Lancaster Cleft Palate Clinic by a research grant from the Gustavus and Louise Pfeiffer Research Foundation.
*Professor of Roentgenology.
**Director, Technical Research.

later, the film is examined to check the patient's position and exposure factors and is filed as a permanent still-film record. The still camera is then replaced by a 16 mm. sound motion picture camera, which is used for most patients, or by a 35 mm. silent motion picture camera. The exposure is made by pressing a single button which, by means of a synchronous motor, activates the x-ray machine, image intensifying tube, sound equipment, camera, and a lapsed time meter which records the duration of the exposure to 1/1,000 minute. The sound track records technical data, instructions to the patient, and sounds made by the patient. A bone conduction microphone is used to record occlusal sounds and clicking joints.

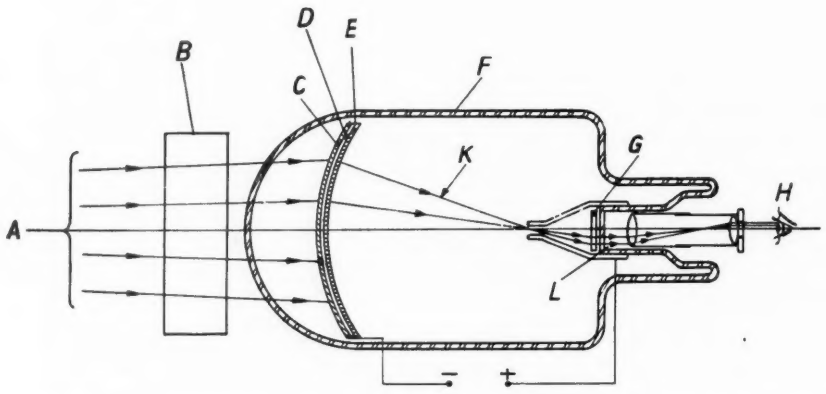



Fig. 1.—The image intensifying tube creates image brightness of sufficient intensity to expose motion picture film (Courtesy North American-Philips). *A*, Incident x-rays; *B*, patient; *C*, aluminum screen carrier; *D*, fluorescent screen; *E*, photocathode; *F*, glass envelope; *G*, viewing screen; *H*, eye of observer; *L*, visible light.

## RADIATION

Table I shows the calibration, made by a radiation safety physicist, of the roentgen output of the tube at several distances between the focal spot of the x-ray tube and the receiving screen. Test films were made at varying factors of kilovoltage, milliamperage, target-skin distance, and with several combinations of filters.

TABLE I. ROENTGEN OUTPUT AT VARYING DISTANCES

| TARGET-SKIN DISTANCE | | | | | |
|---|---|---|---|---|---|
| CM. | IN. | KV. | MA. | FILTER (MM.) | R/MIN. |
| 31 | 12.2 | 75 | 5.0 | 1.0 Al | 24.8 |
| 31 | 12.2 | 75 | 5.0 | .27 Cu | 4.4 |
| 31 | 12.2 | 70 | 2.5 | 1.0 Al | 12.8 |
| 31 | 12.2 | 70 | 2.5 | .27 Cu | 2.2 |
| 51 | 20 | 75 | 5.0 | 1.0 Al | 9.2 |
| 51 | 20 | 75 | 5.0 | .27 Cu | 1.6 |
| 51 | 20 | 70 | 2.5 | 1.0 Al | 4.7 |
| 51 | 20 | 70 | 2.5 | .27 Cu | 0.8 |

With heavy filtration (0.27 mm. copper), it was found that satisfactory pictures could be obtained with radiation factors ranging from 70 to 78 kv. and from 2.5 to 4.0 Ma. It is apparent that the cineroentgenographic patient receives no more radiation in 1 minute than a patient receives during an average exposure of one lower molar periapical film of intermediate speed.

Most authors consider 20 to 25 r the maximum skin dose to which cineradiographic patients should be subjected. It is not envisioned that it will be necessary to expose patients to more than 10 r. Accurate records of both the patient's and the operator's doses are maintained.

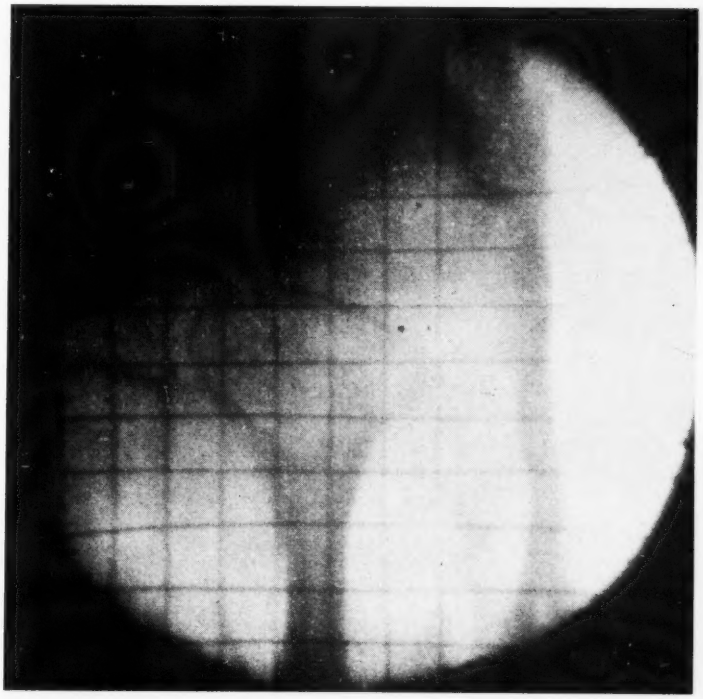


**Fig. 2.—An anteroposterior projection of the condyle is seen on a print made from a single frame of motion picture film.**

ROENTGENOGRAPHIC ENLARGEMENT

An enlarged or magnified image can be produced by placing the object closer to the target without an increase in the target-film distance. If the target area is large (1.0 to 1.5 mm. in dental machines), such enlargement is accompanied by an undesirable blurring of the image border. This phenomenon is known as geometric unsharpness and is caused by overlapping of the divergent x-rays. With smaller focal spots, however, which are possible only with rotating anode tubes, a 2 times enlargement can be produced without visible blurring of the image.

In this apparatus, a 0.3 mm. focal spot, rotating anode tube is used, and the distance from the target to the receiving screen of the amplifying tube is 26 inches. To produce a 2 times enlargement requires placement of the condyle under ex-

amination at a spot 13 inches from the target. The opposite side of the head is then only 7 to 8 inches from the target. At an 8 inch target-skin distance, the skin dose would be higher than at greater distances. The dose rate at this distance was calibrated and shown to be 7.2 r per minute. This compares in 1 minute of exposure with the amount delivered by the average dental machine in 3 seconds and, therefore, does not make the technique prohibitive.

The advantages of the enlargement technique are: a larger picture of the field, details become perceivable which cannot be discerned in the smaller picture,[4] and scattered radiation reaching the screen is reduced.

To determine the degree of roentgenographic enlargement and, thereby, calculate the actual anatomic excursions, a metal ball bearing (being round, its image cannot be elongated or foreshortened) of 4.8 mm. diameter is attached to the patient's face directly above the joint being examined. This ball bearing becomes magnified to the same extent as the joint structures. A wire grid with 10 mm. openings is placed in contact with the receiving screen of the image amplifier and is not subject to enlargement. Therefore, on the finished film, a simple ratio between the size of the shadow of the ball bearing and the grid meshes determines the actual anatomic measurements.

Each patient is filmed with the head inclined 20 degrees laterally and 10 degrees horizontally. Gravity may thus influence the motion, but to what extent is not known. Also, the rays pass through the condyle at 20 degrees to the vertical plane of the condyle. In the anteroposterior projection (Fig. 2), the central ray is directed through the orbit, the head is inclined 30 degrees to the floor, and the sagittal plane is deviated 20 degrees laterally after a technique described by Grant and Lanting.[5]

## INTERPRETATION

Although improvement can and will be made in the production of the films, they are of sufficient quality to permit interpretation. Since condylar action takes place rapidly, frame-by-frame analysis becomes desirable. While detail is acceptable when the motion picture film is running, a stationary frame gives a less sharp image. Homemade attempts at tracing presented quite a problem and left much to be desired. However, with the help of the newest electronic aids,* raw data can be reduced to a more meaningful form. The analysis is accomplished on an instrument known as a Boscar at the University of Dayton Data Processing Laboratory. Single frames appear on a large screen and, by digital manipulation, two cross hairs are positioned on the specific point to be plotted. A reference line is then constructed on the face of the Boscar tangent to the shadow of the ball bearing and the superior border of the external auditory canal. This tangent serves as a fiducial or orienting mark, and on all readings on succeeding frames the tangent line is superimposed over the reference line on the Boscar. The center of the shadow of the ball bearing was chosen as the center of the coordinate system. When the cross hairs are positioned over the selected point, a beam of light activates an IBM punch-card ma-

*University of Dayton Data Processing Laboratory.

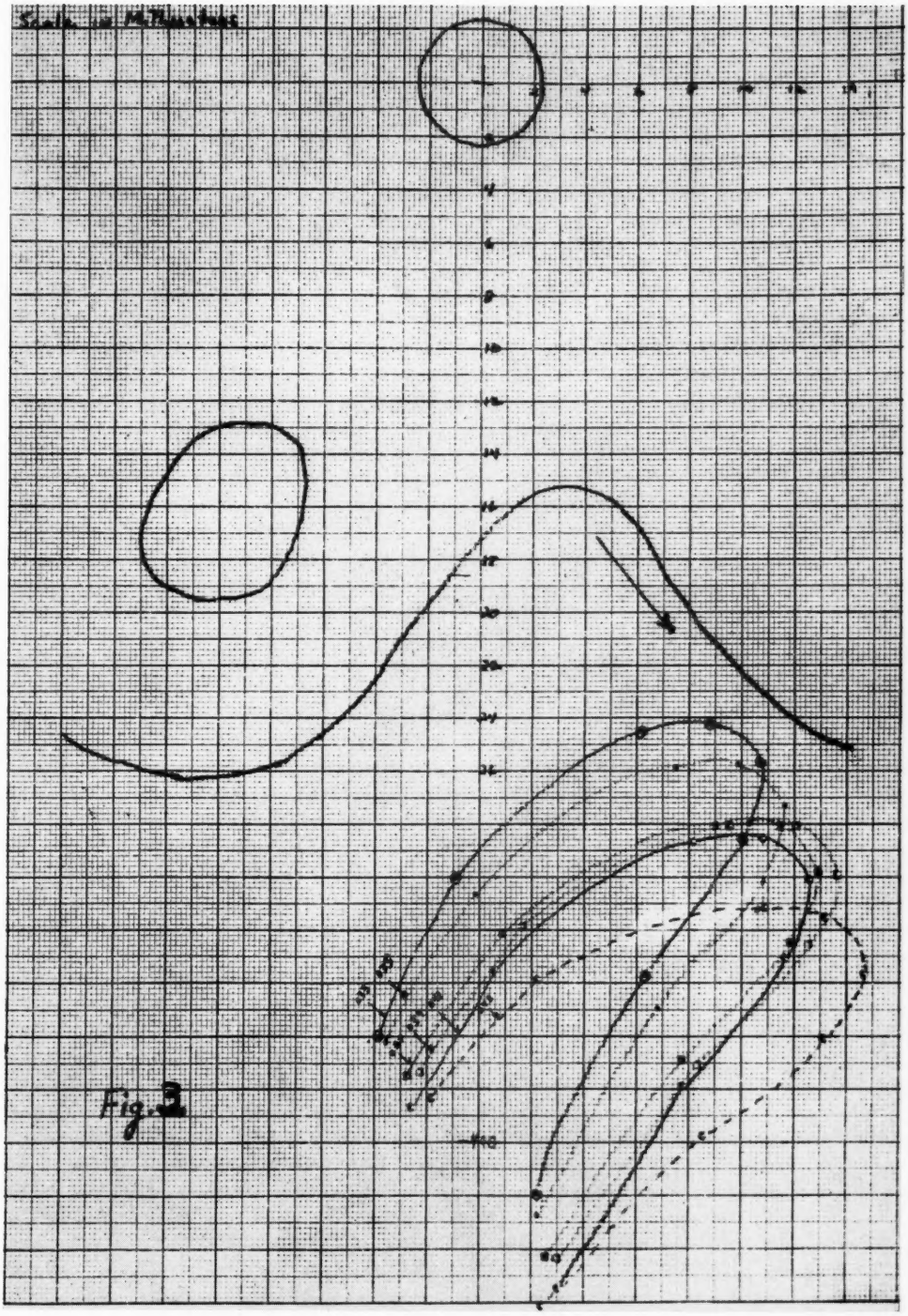


Fig. 3.—An Electroplotter marks eight points around the condyle for each frame. The outline of the condyle is recorded by connecting these points. The O point of the x and y coordinates is the center of the 4.8 mm. ball bearing (top).

chine, and the x and y coordinates of the point (with reference to the center of the ball) are punched, and their numerical equivalent is typed simultaneously on another paper. X and y readings are carried out in this manner for each of eight preselected points around the condyle in each frame.

The next step is to plot these readings. The punch cards are fed into an Electroplotter which automatically marks the x and y position of each point on graph paper. By connecting these points, the outline of the condyle is produced (Fig. 3). When the same procedure is repeated for succeeding frames, condylar movement becomes apparent. The resulting drawings are serial tracings of selected frames from complete functional cycles and give a picture of split-second motion. They are, therefore, dynamic serial tracings as opposed to the static serial tracings produced with still roentgenograms where the mandible must necessarily be held stationary in certain positions. While the latter, of course, are useful, the dynamic serial tracings can give us an idea of what happens between the static positions recorded on still films and also an idea of what takes place during free and natural, unrestrained function.

## RESULTS

The analysis of the pictures of only the first two subjects have been completed and, certainly, no conclusions can be made at this time. Gross movements are

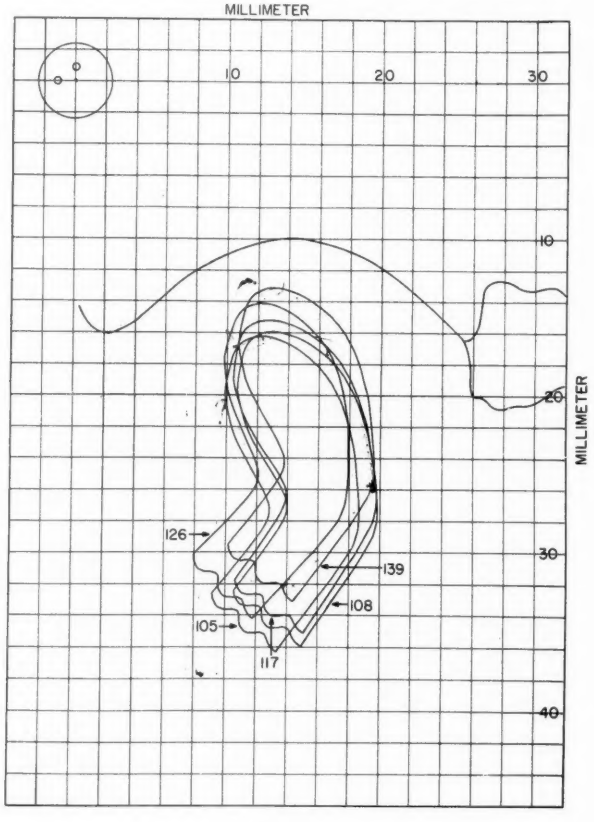
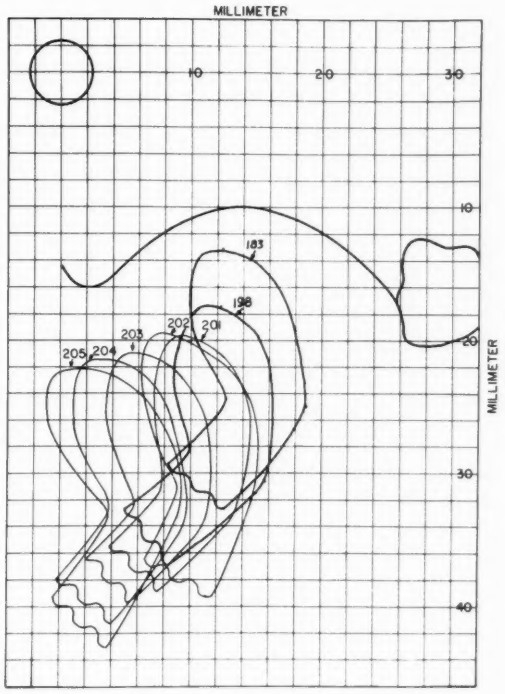



Fig. 4A.


MILLIMETER
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MILLIMETER
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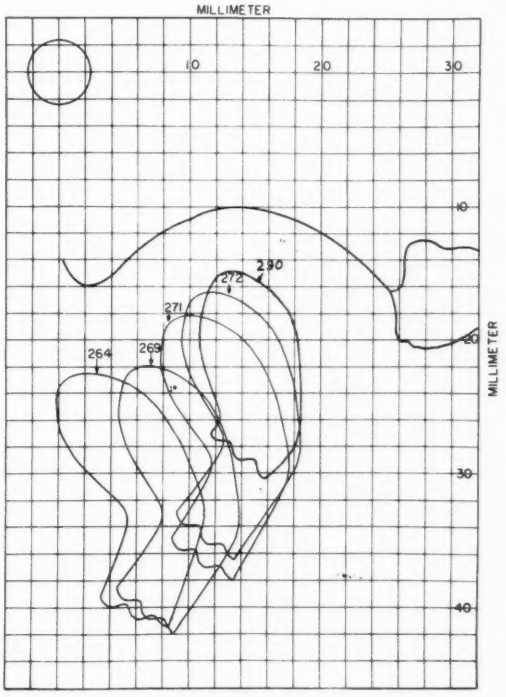
203
204
205

Fig. 4*B*.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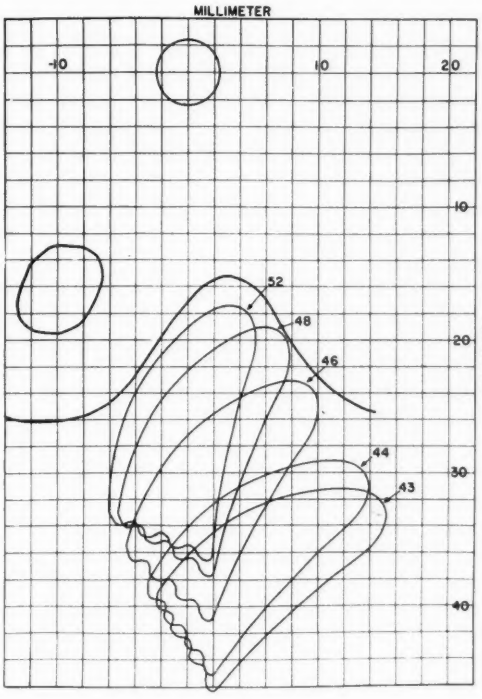
MILLIMETER
264
269
271
272
280

Fig. 4*C*.

obvious. More detailed analysis will require additional study on many more subjects. The results, however, are most interesting and show definite promise. The first three plottings are from films of a 23-year-old woman, with a full complement of natural teeth. She was not chewing on a bolus of food, but merely moving the mandible at the instruction of the operator. In Fig. 4*A*, the condyle goes from rest position to occlusal position, the entire movement occupying 34 frames. The tracings show that point 5, the most superior point on the condyle, moves posteriorly 0.4 mm., then up in a straight line 3 mm. At the same time, point 8 (on the posterior surface of the neck of the condyle) moves back 1.0 mm., forward 2.5 mm., and then back again 1.5 mm. as it moves up into the fossa. This would tend to indicate a definite rotational motion as the condyle moves up to its occlusal position. A certain degree of error must be assumed to exist in measurements. This is introduced by the unsharpness of the image border inherent in roentgenograms. Therefore, the importance lies not in the exactness of each measurement per se, but in the relative values of the several measurements.

In Fig. 4*B*, the condyle moves from its occlusal position to the wide-open position. In 22 frames (since the camera operates at 24 frames per second, this consumed 0.9 sec.), the superior point 5 drops down 4 mm. with no forward movement. Point 8 (on the posterior surface of the neck of the condyle), at the same time, moves anteriorly 3.5 mm. Thus, point 8 seems to be describing an arc about some point in the condyle. After this initial "rotary drop," superior point 5 moves downward and forward along a fairly even path, but point 8 (on the posterior surface of the neck of the condyle) continues to swing through an arc indicating a combination of translation and rotation. A slight horizontal "plateau" is noted at frames 201 and 202 between the end of the "rotary drop" and the start of the downward and forward and downward glide. Fig. 4*C* depicts the closing movement up to the level of the rest position. The pattern is somewhat the same in reverse, with the "plateau" occurring at a slightly lower level. Whether this "plateau" is of any significance is not known. Whether it will be seen in other patients, or even in other opening and closing cycles in the same patient, has not been determined.

The tracings in Fig. 5 are from a 19-year-old girl with normal occlusion. In Fig. 5*A* of this series, the jaws are open wide at frame 43, at which point she bites a wedge of hard apple on the same side. There is an upward translation and rotation of the condyle to the fully closed position in frame 52 (lapsed time 0.4 sec.). Note that the condyle encroaches closely upon the anterior slope of the fossa, possibly because of the extreme force exerted initially on the unbroken bolus. Fig. 5*B* is the opening half of this first chewing cycle. The extent and path of the downward excursion are nearly identical with that of the upward arc (frames 52 to 80, 1.1 sec. elapsed time), but the degree of the rotation of the condyle at the open position is slightly less than that at the initial bite. Fig. 5*C* shows the second upward excursion, from frame 80 to frame 102 (1 sec.). The rotation and translatory path are similar to the previous excursion. However, the superior point on the condyle does not appear to encroach quite as closely to the slope of the fossa and, in the closed position, it is about 3 mm. lower than its closed position at the end of the first excursion. This may be because the initial bite was more forceful, and the teeth may have cut cleanly through the apple. On the second closure, it may be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MILLIMETER
52
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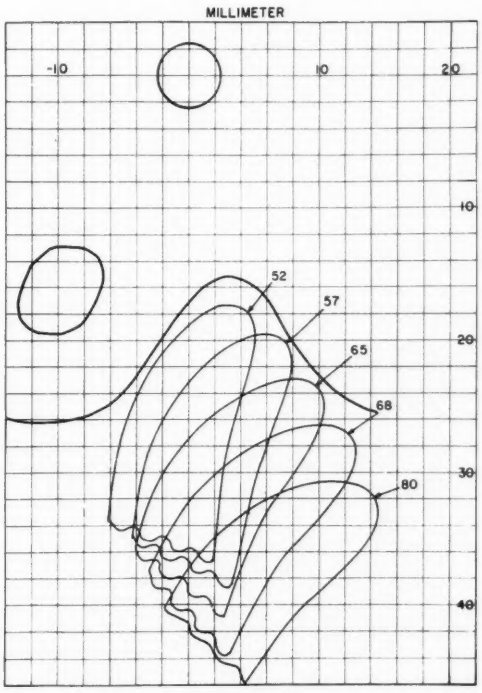
44
43

Fig. 5A.


MILLIMETER
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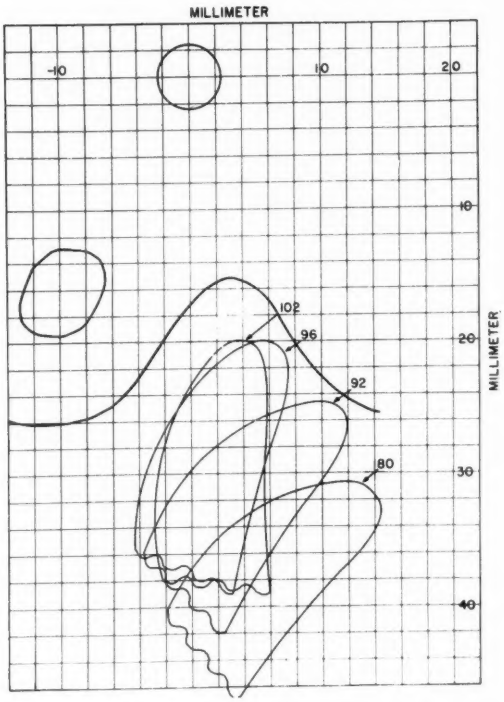
57
65
68
80

Fig. 5B.


MILLIMETER
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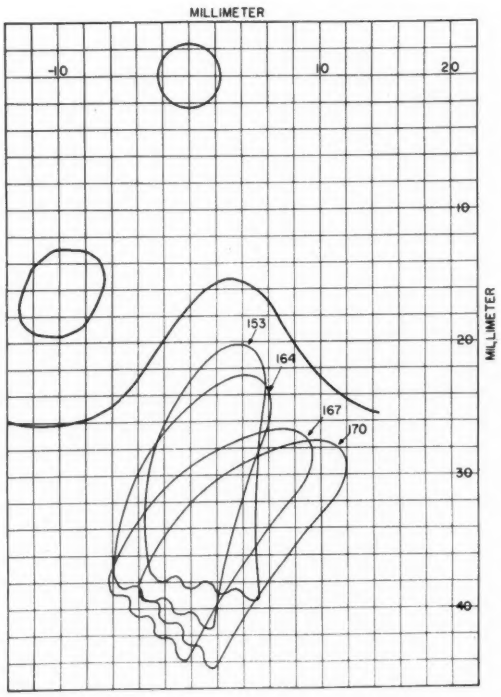
MILLIMETER
102
96
92
80

Fig. 5C.


MILLIMETER
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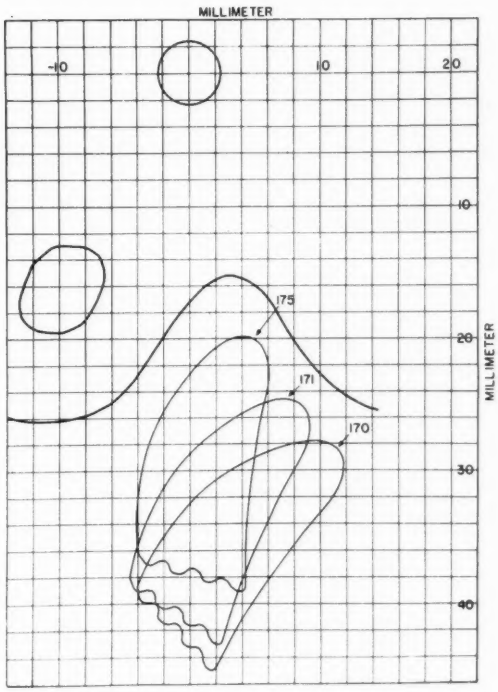
MILLIMETER
153
164
167
170

Fig. 5D.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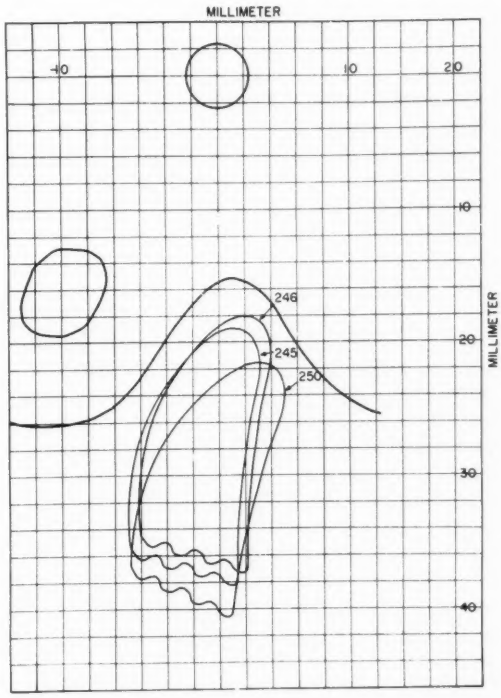
MILLIMETER
175
171
170

Fig. 5*E*.


MILLIMETER
-10
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20
10
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30
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MILLIMETER
246
245
250

Fig. 5*F*.

that less force was applied and/or that the bolus was then broken, and the teeth did not get through all of the pieces.

The pattern of frames 102 to 153 seems to indicate lateral grinding of the bolus and Bennett movement, for the plotted points are a confusing mass of closely related movements. In Fig. 5*D*, the patient opens again from frame 153 down to 170 (0.8 sec.). The "plateau" effect noted in the previous patient is now somewhat apparent, and the condyle is not as far down or forward on the eminentia as it was previously. Fig. 5*E* is the closing excursion of this same cycle (frames 170 to 175)

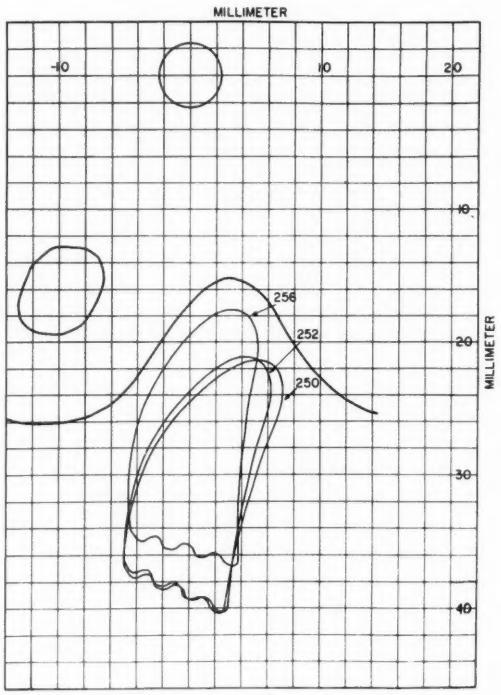


Fig. 5*G*.

and shows the same general path as that at the opening. The condyle finally seats itself in almost exactly the same closed position from whence the cycle originated in frame 153. This closure was accomplished in 0.2 sec., probably indicating that the bolus now offers less resistance although, in the fully closed position, the condyle does not seat itself as high in the fossa as on the initial closure. Figs. 5*F* and 5*G* show the final chewing cycle before deglutition and reveal rotation as the condyle is depressed, but little forward translation.

## DISCUSSION

In reviewing the complete series of the second patient, one observation stands out. The most superior and posterior position in the fossa assumed by the condyle occurs at the end of the first bite on the intact wedge of apple. Upon the final closure, prior to swallowing, the condyle again assumes this same superior position, but at no time is it again observed in such a retruded position.

Not every frame in these serial plottings has been drawn, for often the movement between two successive frames is almost identical, and the outlines would be superimposed. This would clutter the picture and make it difficult to read. However, when the points of each successive frame are plotted and connected, the result is not a smooth curve or straight line, but rather a zigzag line. Some of this undoubtedly is an inherent error in the reading and plotting; how much is not known. But some of it may also be due to the interaction of the several muscles as their action starts or stops, or increases or diminishes. In normal movements, these should be minimal, but in movements where so-called "muscular confusion" exists, they may be exaggerated. It is interesting to speculate at this time whether further studies will uncover any patterns to either these normal or abnormal movements.

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4001 Spruce St.
Philadelphia 4, Pa.
124 N. Lime St.
Lancaster, Pa.

# CERTAIN OBSERVATIONS ON A COMPLETE DENTURE PATIENT

## Part III: Consideration of the Results From a Neuromuscular Viewpoint

G. A. LAMMIE, Ph.D., B.Sc., H.D.O., L.D.S.,* H. T. PERRY, JR., D.D.S., M.S.D.,** AND B. D. CRUMM***

*Northwestern University, The Dental School, Chicago, Ill.*

COMMENT MUST FIRST BE made on the observation of a reproducible muscular position of the mandible in an occlusal position 3 mm. closed from the rest position. In the case described, it was noted that marks on the upper and lower occlusion rims came exactly together when closure was effected at short or long time intervals. One of the writers can recall other patients from his clinical experience who showed a similar ability. However, a larger group of patients exists where frequent testing shows a small deviation of the mandible in an anteroposterior direction. Finally, another group of patients is seen clinically which demonstrates more random closure paths, and a large deviation of anteroposterior mandibular positions result. On the basis of observations of some of this group, some workers believe that once the teeth are lost, closure always becomes random in nature. To understand these observations, it is necessary to review the relevant neural physiology.

There are recognized, in higher members of the vertebrate scale, two general levels of nervous activity. One is the reflex level which is considered innate and devoid of consciousness; it is an automatic chain of action which is initiated by the stimulation of some sensory end-organ. The second is consciousness itself, and has its origin in nerve cells within the cortex; it is, in broad terms, the voluntary or the volitional act.

In the evolutionary development of our cerebral cortex, many of the lesser sensory-motor duties (reflex) have been relegated to lower level centers. The thalamus is one such center which receives and sorts the basic sensory modalities of temperature, pain, pressure, etc. The cerebral cortex, particularly the parietal cortex, correlates through synthesis and elaborates these primary sensations. Thus, it has the ability to discriminate gradations of sensations and intensity. It will localize sensation, differentiate weight, texture, and form. Primary to the problem at hand, the cortex will utilize proprioceptive and tactile signals to recognize and

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*Formerly visiting Associate Professor of Dental Materials.

**Instructor, Department of Orthodontics.

***Prosthetic Laboratory Technician.

localize spatial relations and postural positions. For the proper perceptions of these, the cortex must integrate all of the sensory information from the exteroceptive, interoceptive, and proprioceptive systems.

Walters[1] has described how civilized man has come to control precisely more and more of the actions necessary to life at a reflex level, thus permitting cerebral activity to deal constantly with his environment. Mastication is an example of an act essential to life which is carried on largely at the reflex level. On the reception of some unusualy sensory stimulus, the masticatory act becomes volitional and is directed from the cerebral level; at that moment, the act of mastication becomes what Sherrington[2] has referred to as the "focal act" and is the dominant feature in a background myriad of reflexes.

Sherrington[3] has remarked on this point when he states that "the transition from reflex action to volition is not abrupt and sharp. Familiar instances of individual acquisition of motor co-ordination are furnished by the cases which in short, simple movements whether reflex or not are by practice under volition combined into new sequences and become in time habitual in the sense that though able to be directed, they no longer require concentration of attention upon them for execution."

With the first placement of the denture, the innate or true reflex closure pattern is still present, but additional information is needed to masticate with the new dentures. With a natural dentition, one "learned" over a period of years with each new addition of teeth and their proprioceptive component, thus adding new degrees of control to the inborn pattern of closure. However, once the teeth are all lost and the periodontal receptors vanish, other sensory stimuli from the oral region are called upon to reinforce the basic pattern that was greatly brain stem reflex. Tactile stimuli from the oral mucosa are utilized to learn a new act (not new to the muscles but new to the brain).

Certainly it is not denied that tactile stimuli always play a roll in mastication with or without teeth, but it is stressed that the tactile stimuli are brought to the fore to assist in the adjustment and function with a new prosthesis.

The same sort of condition exists in our everyday experience with clothing. Tactile endings are continuously stimulated, but a cerebral-level curtain is drawn to these stimuli so that they are not brought to the level of consciousness unless through volition or disagreeable fit. In the placement of a new filling or bridge, the tongue constantly searches and magnifies the new object to consciousness, but within a few days all conscious recognition of the new replacement is again shrouded by a cerebral-leveled curtain unless we ourselves raise it by concentration or function raises it by pain.

## LEVELS OF FUNCTION

There thus exist, then, two principal levels of function, and each level may be reinforced by other oral stimuli wherein the need arises.

A. Reflex
B. Volitional
} Reinforced

The proprioceptive nerve endings are present within and about all joints, as well as the surrounding musculature. Afferent impulses from these receptors are constantly being discharged into the central nervous system giving information regarding tension and position. The temporomandibular joint is unique in that a third group of proprioceptive fibers direct its action; the periodontal membranes of the teeth are endowed with a large number of proprioceptive receptors (Fig. 1). Sherrington[3] showed that pressure on the teeth or gingivae of the decerebrate cat caused masticatory movements and considered the proprioceptive impulses partially responsible for this activity. Corbin and Harrison[4] have demonstrated

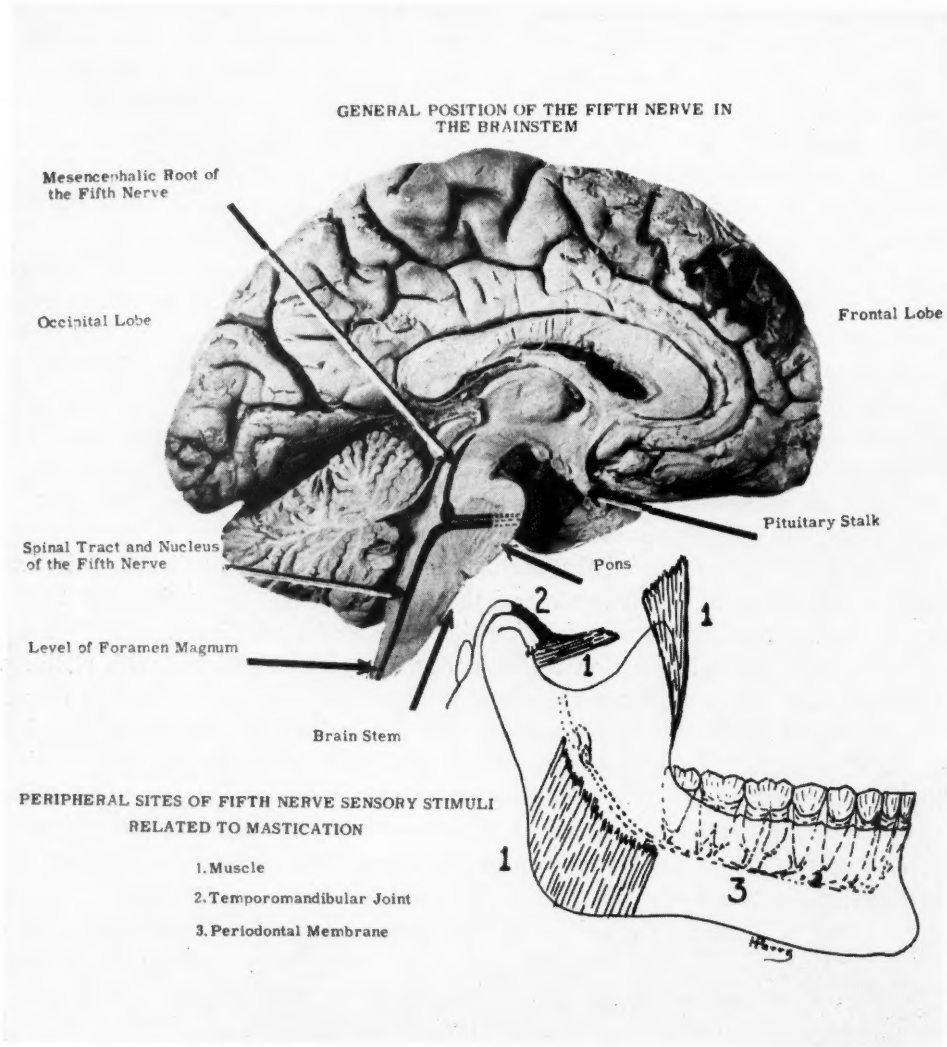


Fig. 1.—The peripheral sites of fifth nerve sensory stimuli related to mastication.

the pathway of this system in the mesencephalon of the cat. One may postulate a certain pressure threshold which acts upon the proprioceptive endings of the periodontal membrane and terminates the elevator contraction as well as initiating the depressor activity. Stretch of the elevator muscles and joint capsules would, on the other hand, induce proprioceptive firing causing a reversal of the act.

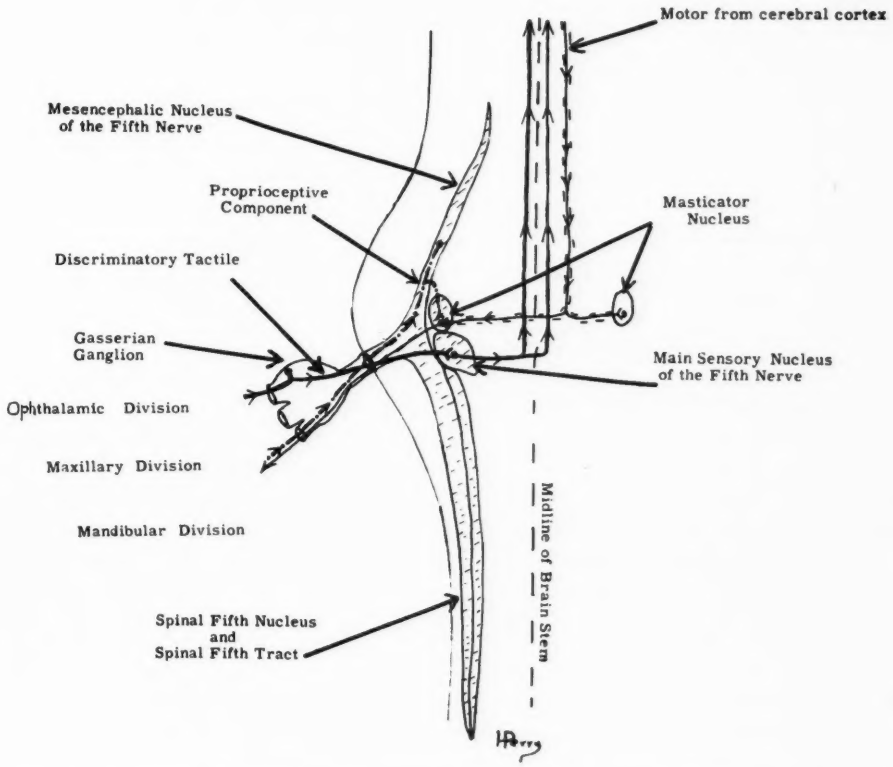


Fig. 2.—A schematic dorso-ventral drawing of the fifth nerve brain stem system.

Afferent proprioceptive nerve fibers from these oral structures are carried in the second and third divisions of the trigeminal (fifth) cranial nerve. Collaterals are found which leave these proprioceptive fibers and synapse with motor cells within the masticator nucleus of the ipsilateral side at the mesencephalic level. Efferent motor fibers from this brain stem nucleus pass to the ipsilateral muscles of mastication via the third division of the trigeminal nerve (Fig. 2).

Mastication in the human being, when carried on as a learned habitual muscle pattern, must also be partly controlled by proprioceptive impulses from the periodontal membrane of the teeth. The observations on incision and mastication observed in the patient with a natural dentition would suggest that stimulation of receptors in the periodontal membrane in different areas elicit different patterns of muscular activity. Stimulation of endings in the anterior teeth causes a forward displacement of the mandible, stimulation in the premolar area, little, if any, dis-

placement, and stimulation in the posterior area, posterior displacement. Because of the observations made while a subject with a good natural dentition chewed a carrot and because of the clinical observation that when a softened horseshoe-shaped wax wafer is inserted between the upper and lower dentitions (for the purpose of registering the rest position of the mandible) a protrusive displacement is usually noted, it would seem that there is an order of dominance of stimuli from these segments. The most "dominant" seemingly arises from the anterior segment, while the most "recessive" is apparently from the posterior segment.

With the natural teeth present, the mandible can be directly, precisely, and forcibly carried into the position of maximal interdigitation as a volitional act. This act is similar to the ability to place the finger to the tip of the nose when blindfolded. Both are acts which are dependent upon the cerebral "awareness" of an end point and occur with cerebral integration of various peripheral signals. The ability to do this in health is dependent upon the nerve endings in the muscles and the joints. It is necessary here to acknowledge the presence of an engram of a terminal intercuspal position at the cerebral level. This would logically be a produce of the proprioceptive system of the muscles of mastication and the temporomandibular joints. Finally, this ability is still observed in complete denture wearers because the two components necessary are present, and they are, of course, the muscle and joint proprioceptor endings. It might be considered that in the case of the vital periodontal membrane and its mesencephalic proprioceptive component, the attainment of the engram is recognized and its position reinforced by the firings from the periodontal membrane. After the loss of the natural teeth and their accompanying proprioceptors, the acknowledgement and reinforcement of a terminal intercuspal position is dependent upon muscle, mucosa, and joint health as well as mechanical denture construction. When either one or all of these features are varied from the original dentition, a new pattern or engram must be established within the cortex, and its acceptance will be dependent upon its effect upon health of all the structures concerned.

## VOLITIONAL JAW MOVEMENT

The impulse for a volitional jaw movement takes origin in the Betz's cells of the masticatory part of the motor area in the precentral gyrus of the cerebral cortex. It is communicated from here via upper motor neurons to the masticatory nucleus of the trigeminal nerve in the mesencephalon from whence its path is the same as described in the reflex arc over the lower motor neurons (Fig. 2).

A reflex closure of the jaw without an intervening bolus must be differentiated from this volitional closure. In this, the sole guide to the muscle pattern, and consequently the path of closure, is the proprioceptive endings in the joint and surrounding muscles. Neither proprioceptive nor touch receptors in the periodontal membrane of the teeth play any part. This movement may lack some of the precision of the volitional movement. It may be that it is an innate and inherent movement pattern present at birth before the eruption of the teeth and certainly remaining after all the teeth are extracted. This act of closure was, however, to

some extent volitional, as he responded to instruction; its initiation was volitional, but its perpetuation was reflex.

But every prosthodontist knows that this reproducible path of closure cannot be determined in every patient. This is the case if the act is entirely volitional. Such a situation may arise as a result of the approach of the dentist to his patient; either a hurried or overefficient manner will certainly result in high order of cerebral activity in the patient. Certain recent Swedish research upon muscle "tonus" is of interest here. Granit and Kaada[5] have stated: "We have observed that most spindles in our preparations maintain a high level of discharge that fluctuates with central events rather than primarily with muscle tension." In other words, muscular end organs which have great responsibility for muscular "tonus" seem more readily affected by cerebral activity than by peripheral stimuli. The patient, on the other hand, may be one who is resistant to suggestion. Often highly intellectual people or those who have been exposed to stress fall into this category. Their reaction is of the volitional type and may take one of two forms. The first is by far the most common and is seen where no teeth, natural or artificial, have been present in the mouth for some time. Here movement is random and is effective over a wide anteroposterior range. A second type of volitional movement is seen and seems to depend on a residual memory of a previously existing intercuspal position, natural or artificial. If a patient has worn a denture in which the intercuspal position is protrusive, and if an interocclusal record for a new denture is being registered directly after the removal of the old dentures, the patient will give the same relation that existed provided a volitional response is made. This latter feature is a point to consider in the construction of immediate dentures. It is possible in certain maxillary-mandibular malrelations to reconstruct a position of mandibular displacement which was present in the natural dentition.

## HINGE VERSUS MUSCULAR POSITION

The question then arises whether a hinge or a muscular position should be recorded when registering the centric jaw relation during construction of complete dentures. In those cases where difficulty is experienced in obtaining a muscular position, the solution is simple; a hinge position must be recorded. When, however, a choice exists, the writers would advocate their preference for a muscular position. First, a masticatory pattern more closely resembling that found in good natural dentitions is permitted. It is possible that the final forward slide of the mandible either contributes to an improved masticatory efficiency, or the appreciation of large or hard resistant food particles which are resisting comminution. Second, whereas ligaments can generally withstand intermittent pressure, they will always stretch when exposed to more constant load. John Hunter was aware of this fact in the eighteenth century, and it became known as the Law of the Ligament[6]. Thus, as long as pressure on the ligament is intermittent, as in mastication, no change will generally ensue. If, however, the patient is one who is subject to clenching of the teeth when exposed to a stress situation, a constant

force will act on the lateral ligament if the retruded position is selected. A condition is present in which stretching of the ligament might occur and allow a posterior displacement of the condyle in the glenoid fossa. Admittedly, few cases of this kind are seen, a fact probably due to the limitation imposed by pain to interocclusal pressure under a hard denture base covering an atrophic lower ridge and to the frequency of unstable lower dentures in similar cases. When the opposing teeth are held in occlusion and a muscular position of the mandible has been chosen, no stretch is imposed on the ligament, and a physiologic joint action is more likely to be preserved. Third, Thompson* points out that if a hinge position is selected for the construction of complete dentures, a pathologic, or potentially pathologic, position of the mandible may be perpetuated. He, too, is of the opinion that a mutilated dentition is not a reliable guide to the correct mandibular-maxillary relation in any plane or direction. He does not believe that the hinge or retruded position is a dependable guide if abnormal function of the temporomandibular joints exists. He contends further that the fact that a position is reproducible does not prove its normalcy. Joint symptoms are often seen in complete denture patients, particularly when the lower appliance is well retained and stabilized, and this may well have existed in the mutilated dentition prior to the dentures.

Although a hinge record is taken, the possibility should still exist to use this as a transfer position, from which an anterior position may be selected on the articulator. The distance of this could be based on the findings of Posselt[7] and Donovan.[8] Its angulation would need to be the subject of further experiment, but it is likely that over such a short range an average value would suffice.

It is pertinent to present some features of mastication seen with the muscular denture. With a bolus which requires the application of considerable force for its initial comminution after incision, the mass is carried back to the first and second molar regions. It will be noted that this is the area of widest occlusal surface, and the large occlusal table will effect a greater amount of breakdown of the food quickly. In this position, too, the masseter acts at its greatest mechanical advantage, its anterior fibers being situated farther from the joint than the bolus, thus giving an advantageous movement. As the jaw is closed, the condyle on the working side is applying load against the lateral ligament of the temporomandibular joint, and at this stage, the joint must be considered load bearing. Gellhorn[9] has pointed out that all muscles, when exerting their maximal force of contraction, do so against ligamentous reinforcement. There is, of course, some reduction of the load on the joint through the balancing contraction of the external pterygoid muscle. That the condyle is retruded posteriorly in the glenoid fossa and accordingly that its further displacement is resisted by the strong lateral ligament is founded on three types of evidence. Observation of the chewing showed a forward slide to the occlusal position after the teeth of the upper and lower jaws approximated. Electromyographically, it was demonstrated that there was marked

*Thompson, J. R.: Personal communication and Oral Physiology, Graduate Course in Orthodontics, Northwestern University, Dental School, 1954.

activity of the posterior fibers of the temporal muscle, an action calculated to retrude the jaw maximally. This activity decreased toward the end of the stroke to allow the final forward slide of the mandible.

### FACETING OF TEETH

Third is the evidence of faceting. It must be assumed that faceting of the teeth is incurred during the mastication of abrasive foods as the teeth come into a position of contact or near contact.[10] Twenty-five dried skulls which had a complete, or nearly complete, dentition were examined. Facets are more easily recognized and delineated on natural teeth than on casts, but there is likely to be some distortion of either the jaw bones themselves or the tooth-alveolus relationship during preparation of the specimens. Only those skulls which showed a perfect intercuspation were accepted in this study; another limiting condition on the selection of the skulls was that the last upper molar had to be more distally placed than the last lower tooth. Lastly, faceting had to be in evidence. As a result of these three limitations, only ten of the twenty-five skulls could be used for close examination of the faceting on the occlusal surface of the last upper molar. It was noted in eight of these that when the mandible was held with the teeth interdigitating maximally, and the facet on the upper molar extended further posteriorly, indicating that in mastication, the mandible must have been in a maximally retruded position at some stage. The remaining two skulls showed over-erupted and unopposed upper third molars. These had facets on their mesial surfaces, but a space existed between the facet and the distal surface of the terminal lower molars when the mandible was held with the teeth maximally occluded. This would again lead to the conclusion that the lower jaw must have been retruded at some stage of the masticatory act. As a concurrent lateral slide of the mandible was noted in the final stage of the masticating stroke, it must be assumed that the "working" condyle lies in a Bennett position, i.e., a border position of the mandible with some lateral displacement. It was apparent that the "balancing" side condyle must be in a protruded and medially displaced position, its position being fixed by the muscles observed to be acting on the joint. As comminution of the food proceeded, the smaller food particles moved forward so that the bolus came to be located over molar and premolar teeth. The mandibular stroke on the "working side" became more nearly vertical, and the forward terminal slide into the occlusal position was not seen. This was accompanied by reduced myographic activity from the posterior temporal fibers. It would thus seem logical to conclude that in this second phase of mastication, the "working side" condyle was not retruded against the lateral ligament and the whole masticatory lead was now borne by the teeth. In this sharing of the load at first between the joint and a few teeth and latterly by an increased number of teeth, we see an arrangement calculated to preserve both the joint and the teeth by adequately distributing the load. Not all foods call forth the first stage of the masticatory pattern described; a softer food which flows rather than fractures produces an E.M.G. pattern which from the start resembles that described in the second stage. The bolus has almost

immediately flowed forward to cover the premolar teeth, and stimulation of receptors in their periodontal membrane may be postulated to call forth a jaw movement with little or no posterior displacement.

Severe pain was noted by the patient with the most open and protruded dentures, and its location was constant, posteriorly on the covered ridge on the preferred side of mastication. The thinner mucosa covering the sharp mylohyoid ridge proved to be the most affected region. Because of its location and because of its exacerbation when eating, it must be inferred that the pain was caused when pressure was applied during the first stage of chewing a hard bolus. Since the inflammation was under the molar area, attention must be directed to that phase when the hard bolus is being comminuted with the jaw in its most retruded position. In the two cases where the severe pain was felt, it should be noted that the largest anteroposterior occlusal distance existed between the first impact, or near impact, of the teeth with the jaw in forced retrusion and the ultimate position of maximal interdigitation. Examination of these cases showed definite prematurities when the teeth were occluded with the jaw in its most retruded position. It is suggested that this is one cause of the pain, and that if a balanced occlusion had existed posterior to the interocclusal position, no discomfort would have been experienced. No pain was felt with the muscular denture; but here the possible posterior displacement is small, and the chances of getting prematurities are accordingly reduced.

These observations suggest that a posterior rather than anterior balanced occlusion may be more important in complete denture restorations.

### INCISAL INTERFERENCE

A balanced occlusion anterior to the position of maximal cuspal interdigitation would appear less important, but this does not imply that incisal interference can be tolerated. This is quite another matter. Incision is an act which is not indulged in to any extent in modern mastication; the use of a knife and fork has made the act more and more socially unacceptable. Moreover, most of the foods which are excised are of the hard type which are fractured before the teeth come into contact. In this condition balanced occlusion cannot help either load distribution or denture retention. Anterior balance will be of most service in these patients, who, as an idiosyncrasy make a protruded nonmasticatory habit occlusion.

A further comment is required concerning the pain. Although in the open and protrusive dentures measurable resting muscular activity was noted, it certainly was not of sufficient amplitude to cause the collection of metabolites and a muscular type of pain in the time period the dentures were present. Either the patient was resistant to this form of myogenic disturbance or its development requires a longer period of time than was examined.

The patient displayed an edematous type of tissue at the juncture of the hard and soft palate, a condition calculated to predispose to a rapid failure of positive retention in the upper denture.[11] It is pertinent to note that, according to the assessment of the patient, retention of the upper denture failed most quickly in the case of the open and protrusive dentures when a balanced posterior occlusion did not exist. In this situation, a combination of unfavorable factors was operating.

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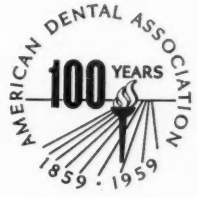
NORTHWESTERN UNIVERSITY
THE DENTAL SCHOOL
CHICAGO, ILL.



# AN ELECTROMYOGRAPHIC ANALYSIS OF THE FUNCTION OF THE BUCCINATOR MUSCLE AS AN AID TO DENTURE RETENTION AND STABILIZATION

DONALD O. LUNDQUIST, CAPTAIN, USA (DC)
*Fitzsimons Army Hospital, Denver, Colo.*

RECENTLY, MUCH NEW INFORMATION relative to the musculature of the masticatory apparatus has been obtained through the use of the electromyograph. Research on mandibular movement, physiologic rest position and centric position, hinge axis, and pathologic conditions[1-7] have contributed to an ever increasing knowledge of muscular function. The electromyograph has become another valuable instrument in aiding dental research. Jarabak[7] and Pruzansky[8] describe the electromyographic equipment and the physiologic basis for the recordings.

## PURPOSE AND BASIS FOR THIS STUDY

This study was undertaken to determine the action of the buccinator muscle as an aid to stability and retention of complete dentures. Reproduction of the anatomy and contour of those portions of the alveolar ridges that have been lost, and proper tooth placement are essential in complete denture prosthesis to restore esthetics and function.[9]

Fish[10] states that the "polished" surface of the denture is "gripped" by the buccinator muscle which aids in stability. Craddock[11] concurs with this view. Fish[12] shows diagrammatically how the middle fibers of the musculature of the tongue and the middle fibers of the buccinator muscle hold a bolus of food between the teeth for mastication. The relatively superior and inferior fibers of the buccinator muscle have a resultant force that tends to raise the upper and depress the lower denture, respectively, thus aiding stability and retention.

If this premise is true on the working side, what muscular activity is taking place on the balancing side? It was postulated that if a bolus of food, thicker than the height of the balancing cusps, was introduced between the dentures on the working side, the balancing side would tend to rise from the basal seat. As the balancing side attempts to rise, would the flange of the working side of the denture be "gripped" by the buccinator muscle, thus providing retention?

## EQUIPMENT

A Grass model III A console electroencephalograph on the electromyographic settings was used. Eight leads were available for recording, and ground leads were attached to all patients. Soldered disks were used as surface electrodes in all tests

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except for the recording of the preliminary data. Electrode paste was used to secure all the surface electrodes and ground leads to the subject. A paper speed of 30 mm. per second was used throughout the recordings. All records were obtained with the patients in a relaxed, comfortable position in a copper-screened room. In obtaining the preliminary data, a one-half inch, 27-gauge monopolar needle electrode was used.

## PRELIMINARY DATA

Because of the intimate arrangement of the facial muscles, with the triangularis, zygomaticus, risorius, orbicularis oris, and buccinator muscles functioning through the modiolus, plus a possible influence from the platysma muscle, it was first necessary to determine whether a surface electrode would pick up the electrical potential of only the buccinator muscle. The presence or absence of overlapping electrical fields[13] from these various muscles had to be determined.

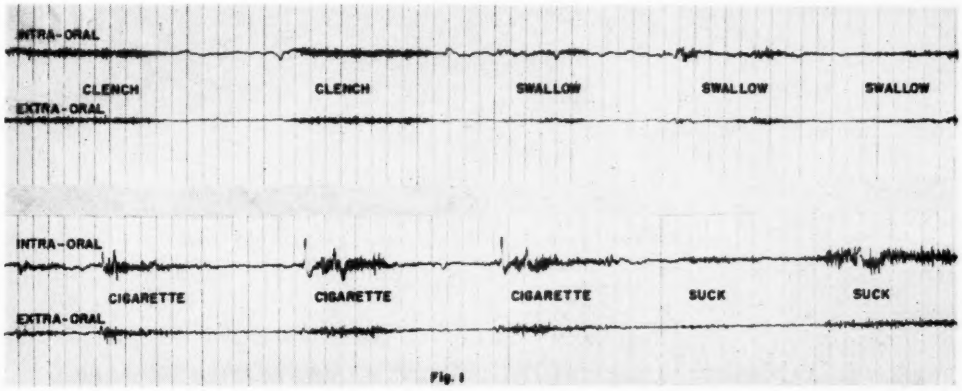


Fig. 1.—The intraoral recording is from the needle electrode inserted into the buccinator muscle. The extraoral recording is from the surface electrode externally applied and opposite the tip of the needle electrode. Note the greater response of the needle electrode and that the surface electrode duplicates relatively accurately the recording from the needle electrode.

Two unanesthetized subjects with well-equilibrated natural dentitions were used. A needle electrode was inserted intraorally through the mucosa into the buccinator muscle. The presence of the tip of the electrode in the substance of the buccinator muscle was determined when the most marked response was recorded on the graph paper when sucking and swallowing motions were made. The needle electrode was placed opposite the lower first molar at the level of the occlusal plane. Then the surface electrode was placed extraorally opposite the tip of the needle electrode. With both electrodes in place, the subjects clenched their teeth, swallowed, drew on a cigarette, and sucked. Repeatedly, a greater magnitude of electrical potential was recorded from the needle electrode. However, the surface electrode duplicated relatively well the recordings of the needle electrode. Because of the ease of application of and the greater comfort to the patient from

the surface electrode, this was the electrode of choice. The conclusion drawn was that the overlapping of electrical fields from the other facial muscles was minimal. Fig. 1 is an electromyogram of one of these subjects performing these movements.

### ELECTRODE PLACEMENT

All further tests were conducted with surface electrodes. The leads were placed so as to record from the left temporalis, right temporalis, left masseter, right masseter, left buccinator, right buccinator, lower orbicularis oris, and upper orbicularis oris muscles.

The electrode for the temporalis muscle was placed over the most anterior portion of the muscle that could be palpated during marked clenching of the teeth in centric occlusion. This location was immediately superior to the outer canthus of the eye. The electrode for the masseter muscle was placed in line with the plane of occlusion and anteroposteriorly in the middle of the muscle as accurately as could be determined by palpation while clenching the teeth. The electrode for the buccinator muscle was placed in line with the plane of occlusion opposite the lower first molar. The electrodes for the orbicularis oris muscle were placed in the midline superiorly and inferiorly to the vermillion border of the lips. The recordings of the temporalis and masseter muscles are considered in this article primarily for correlation with the chewing cycle.

### SUBJECT MOVEMENTS

After the electrodes were pasted in position, all subjects were instructed to repeat the same motions three times in this sequence: (1) open and close firmly together, (2) clench the teeth together, (3) suck, as if through a straw, (4) draw on a cigarette, (5) place one peanut on the last tooth on the left side, chew, and swallow it in the normal manner, (6) repeat this on the right side, and (7) chew ten peanuts normally on the side or sides of the individual's choice. (Two subjects chewed the peanuts bilaterally.)

The first four actions were used to determine if any variations existed from an electromyographic standpoint between the right and left sides. It was soon apparent that all subjects who were normally unilateral chewers showed slightly greater deflections of the styli that were recording the electrical activity from the temporalis, masseter, and buccinator muscles on the chewing side of preference, in normal opening and closing movements.

The results discussed in this article will deal only with the chewing motions, as it was not felt that the first four motions revealed anything of clinical significance other than the fact that the habitual chewing side of unilateral chewers could easily be determined by the recording of the greater electrical potential from the muscles on that side.

### NATURAL DENTITION

Six subjects with natural dentitions, having no discernible occlusal disharmonies, were tested as a control. Fig. 2 is a portion of one of the recordings of one

subject from this group; all others showed similar results. The subject had placed one peanut on the lower left second molar and then proceeded to chew it in his natural manner. It is easily discernible that the activity recorded from the muscles on the working side is consistently of greater magnitude than the activity from the muscles on the balancing side. This pattern, that of the greater magnitude of deflection on the working side, was observed on all subjects. Also, the buccinator muscle of the working side generally elicited the greatest response between masticatory strokes but, also, had a somewhat less marked response at the time of the stroke.

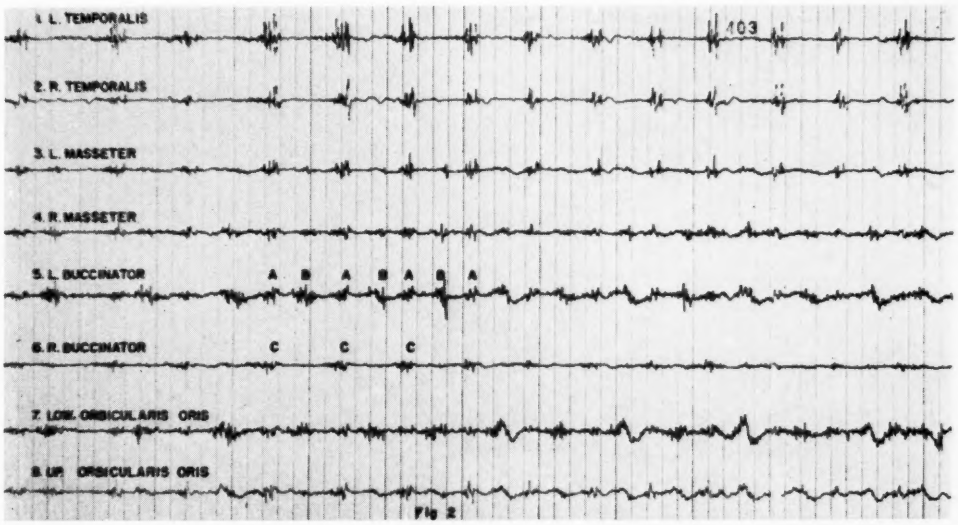


Fig. 2.—This subject is chewing one peanut on the left side. A greater potential is recorded from the muscles of the left side than from those of the right side. *A* represents the final closing stroke prior to reopening as indicated by the marked responses elicited by the temporalis muscles. *B* indicates the contraction of the masseter muscle as the teeth engage the bolus of food. *C* is the contraction of the buccinator muscle on the balancing side at the time of the final closing stroke but is much less marked than that of the left side.

The masseter muscle appears to have two active periods of contraction during a masticatory stroke. One occurs simultaneously with the contraction of the temporalis muscle, and the other occurs between contractions of the temporalis muscle. The later contraction probably represents the initial contraction as the teeth start to move through the bolus of food.

The buccinator muscle on the balancing side elicited its greatest response at the same time the temporalis and masseter muscles were actively contracting. This same observation was noted on 12 of the 17 subjects tested.

### MAXILLARY DENTURE AND MANDIBULAR REMOVABLE PARTIAL DENTURE

Six subjects with complete maxillary dentures and bilateral distal extension mandibular removable partial dentures were tested. Two subjects had dentures

with anatomic teeth, two with modified anatomic teeth, and two with nonanatomic teeth (Hardy cutters with balancing ramps). The dentures with the anatomic teeth had been remounted on the articulator, and a balanced occlusion developed. The occlusion of all of the dentures was balanced in the mouth by using an intraoral central bearing device (Coble Balancer) after the subject had worn them for a period of from 7 to 10 days. No subject was tested until he had worn the dentures for a period of 6 weeks. Each subject was fully adjusted to his dentures before testing and felt that he could use them competently.

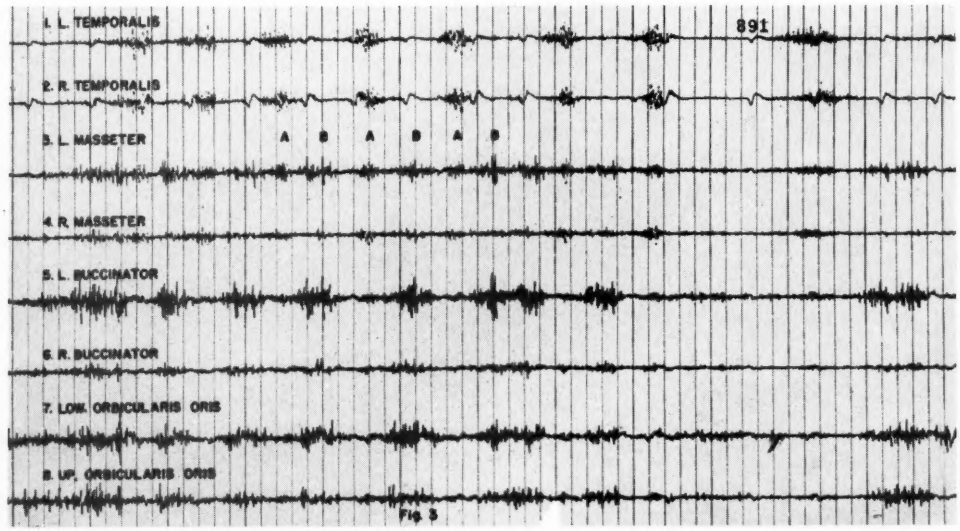


Fig. 3.—A record made while the subject is chewing one peanut on the left side. A greater potential is recorded from the muscles of the left side than from those of the right side. *A* indicates the time of the final closing stroke prior to reopening. *B* indicates the contraction of the masseter muscle as the teeth engage the bolus of food. The most marked contraction of the buccinator muscle of the left side occurs as the teeth engage the bolus of food.

Fig. 3 is a portion of an electromyogram of one of this group. The patient is chewing one peanut on the left side. The electrical activity recorded from the buccinator muscle is not as pronounced on the balancing side as it is on the working side; nor does the balancing side have the same pattern of contraction as in the previous case. The working side buccinator muscle (left) shows a very marked contraction, generally between the contractions of the temporalis muscle. *A* indicates the final closing stroke of the temporalis muscle prior to reopening. A marked contraction of the masseter muscle is occurring at this time. Neither buccinator muscle, however, is recording a contraction. *B* indicates the maximum contraction of the buccinator muscle which occurs between contractions of the temporalis muscle and at the same time that a greater amount of electrical activity is recorded from the site of the masseter muscle. No marked contraction of either buccinator muscle is recorded at the time of the closing stroke, as on the first subject (*C* in Fig. 2).

Individual variations were found in every subject so that only generalized results can be determined. There was no variation observed in relation to the type of tooth used. The chewing side showed the greatest magnitude of deflection for all the muscles recorded.

### COMPLETE MAXILLARY AND MANDIBULAR DENTURES

Five subjects with complete maxillary and mandibular dentures were tested. The occlusions of the dentures of these subjects varied; one was anatomic, two were modified anatomic, one was nonanatomic with balancing ramps, and one was a nonanatomic without balancing ramps. A balanced occlusion had been obtained in all dentures. No variations in the recordings could be attributed to the type of tooth or occlusal form used.

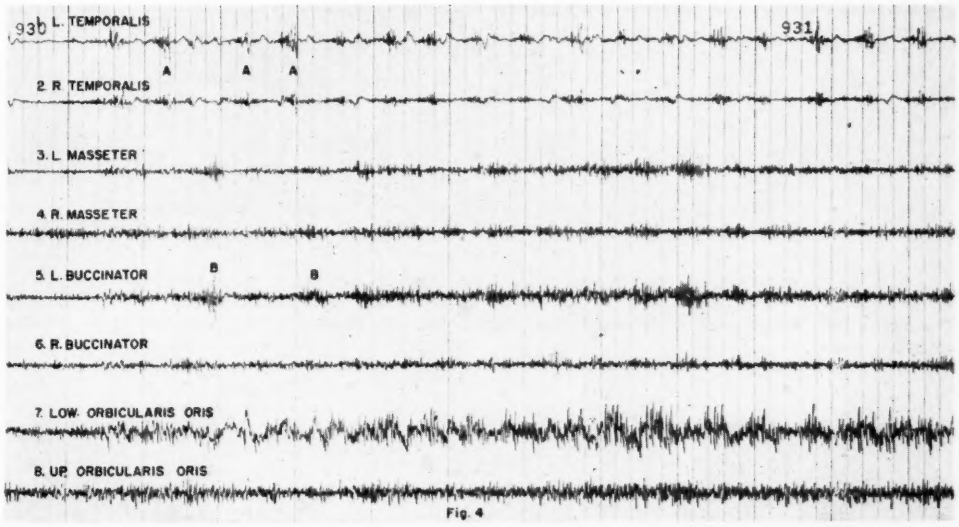


Fig. 4.—A record made while the subject is chewing one peanut on the left side. The recordings of the left side are more marked than those of the right. However, a definite sequence does not appear as in the preceding records. This variation is felt to be due to the fact that the subject was an extremely nervous, middle-aged woman.

Fig. 4, a portion of the recording of one of these patients, shows the same type of recording as the previous ones, namely, that the greatest deflections of the styli are on the chewing (left) side. The buccinator muscle on the balancing (right) side shows practically no variation throughout the entire record. The buccinator muscle on the working (left) side shows a marked response simultaneously with that of the left masseter muscle. Here again, it is observed that this contraction of the buccinator muscle is between contractions of the temporalis muscles. This subject was a nervous, middle-aged woman. It is readily observed that the recording does not have a definite sequence as in the preceding records. However, this record shows a variation that may occur because of the type of subject.

Fig. 5 is an electromyogram of a subject chewing one peanut on the right side. As before, the contraction of the buccinator muscle is greatest between the contractions of the temporalis muscle. Here, however, the buccinator muscle is not contracting between every contraction of the temporalis muscle as is seen in Figs.

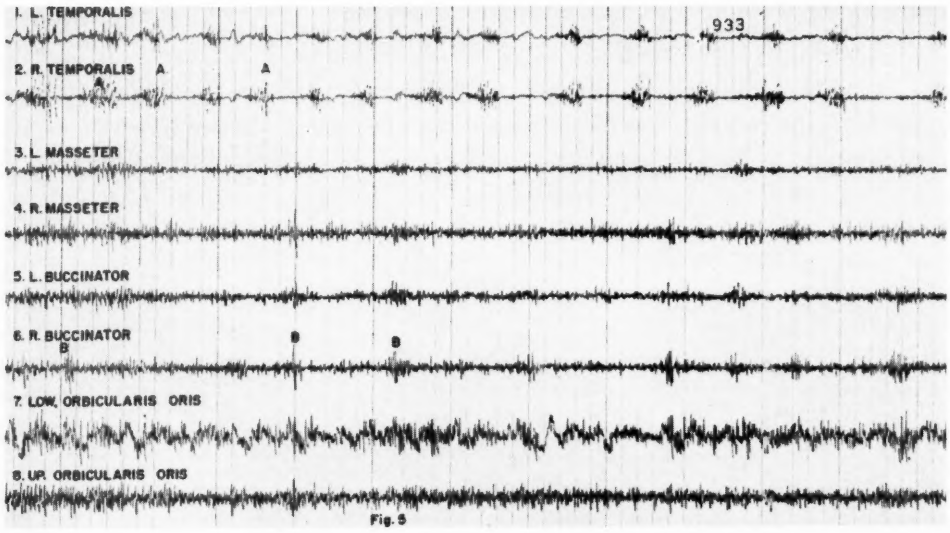


Fig. 5.—A record made while the subject is chewing one peanut on the right side. The recordings of the right side are greater than those of the left. The marked contractions of the right buccinator muscle *B* occur irregularly but are always between contractions of the temporalis muscle *A*.

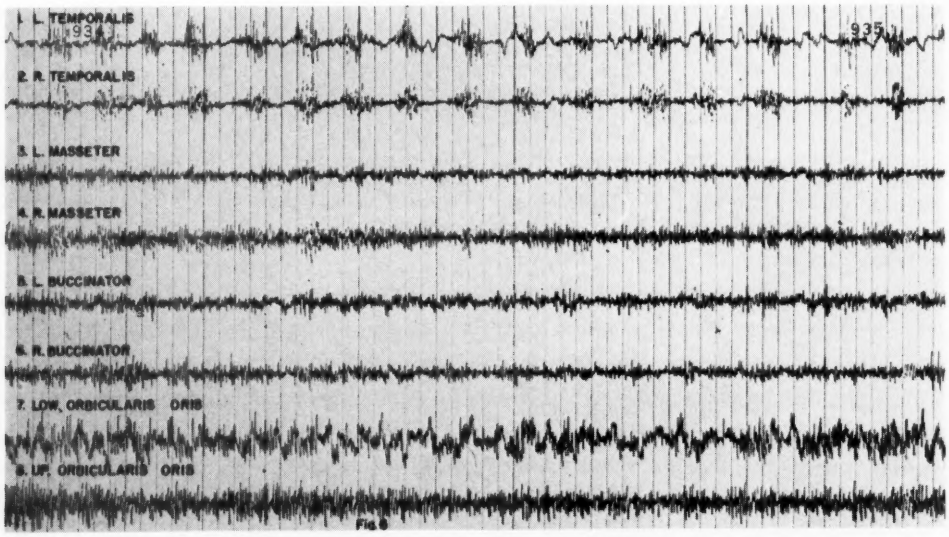


Fig. 6.—A record made while the subject is chewing ten peanuts bilaterally. The recordings of the right and left buccinator muscles are approximately equal. Only in bilateral chewers are the buccinator muscles effective bilaterally in aiding denture stability and retention.

2 and 3. This maximum contraction of the buccinator muscle is irregularly spaced throughout the record.

Fig. 6 is an electromyogram of a subject who was one of two bilateral chewers tested, chewing ten peanuts. Both of these subjects had worn dentures longer than 5 years. They had been instructed when the dentures were first inserted to chew on both sides, and had done so since the time of insertion. This record indicates that the left temporalis muscle is eliciting a slightly greater response than the right temporalis muscle while the right masseter muscle has a slightly greater response than the left masseter muscle. The action of the buccinator muscle appears to be uniform throughout as to right and left sides and also shows a rather uniform contraction throughout the entire record.

Alteration of the contour of the buccal surface of the buccal flange from a concave surface through various stages to a convex surface did not significantly change the recordings. It was presumed that the buccinator muscle continued to contract in the same manner regardless of the shape of the buccal surface of the buccal flange. This should not be construed to indicate that denture contour has no effect on retention and stabilization. It indicates that the buccinator muscle has only one method of contraction; and if the denture contour is favorable, its action will increase retention and stability. This was the subjective finding reported by the subjects on whom these tests were conducted.

The recordings of the orbicularis oris generally indicated only that the lower lip is more active than the upper lip.

## SUMMARY AND CONCLUSIONS

1. Electromyographic recordings of the buccinator muscles of 17 subjects with natural and artificial dentitions were obtained.

2. The muscles on the working side of unilateral chewers contract more vigorously than those on the balancing side in normal opening and closing movements.

3. The buccinator muscle contracts most actively and exerts pressure on the buccal flange only on the working side of unilateral chewers.

4. The action of the buccinator muscle on the balancing side is not felt to be significant in aiding the stability and retention of the dentures in unilateral chewers.

5. Two contractions of the buccinator muscle on the working side were recorded for 12 of the subjects tested. The first occurred at the time of the closing masticatory stroke just prior to reopening. The other occurred as the teeth first met the resistance offered by the bolus of food.

6. The various types of occlusion used in this test had no effect upon the results.

7. The buccinator muscle is effective bilaterally as an aid in denture retention and stabilization only if the patient is a bilateral chewer.

8. Alteration of the contour of the buccal aspect of the buccal flange of the dentures did not show any appreciable variation in the electromyographic recordings.

9. The electromyographic recordings support the theory of the action of the buccinator muscle as described by Fish.

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Fitzsimons Army Hospital
Denver 8, Colo.

# TESTING OF OCCLUSAL PATTERNS ON THE SAME DENTURE BASE

VINCENT R. TRAPOZZANO, D.D.S.
*St. Petersburg, Fla.*

THE OBJECTIVE OF THIS investigation was to test patient reaction to and the relative efficiency of two types of posterior occlusal patterns: (1) the 20-degree posterior tooth (anatomic) and (2) the Hall's posterior tooth (nonanatomic). The occlusal patterns were constructed on a common denture base. The use of a common denture base permits a positive control of this factor and allows for interchangeability of the entire occlusal pattern. In the final analysis, any comparative evaluation of occlusal patterns and designs will have limited value unless the investigation is carried out in the patient's mouth under normal conditions of wearing dentures. As nearly as practicability and experimental limits permit, *all factors* were kept constant except the factor being tested, which in this instance was the occlusal patterns.

There is a wide difference of opinion among complete denture prosthodontists as to the various techniques and materials which are best suited for complete denture construction. More important, there is a wide variance of opinion of what constitutes "basic concepts." There is also much difference of opinion as to the type of movement the mandible is capable of making during function. Conclusive evidence has not been supplied as to which of these movements it is essential to record and reproduce in the construction of complete dentures. Some dentists believe that teeth should be set in a "balanced occlusion"[1]; others adhere to the idea that teeth should be set on a "flat" or "fixed" (compensating) curve, or on a "reverse" curve,[2] and still others believe that teeth should be set in a manner which represents a combination of these concepts.

Disagreement extends to include the type of teeth to be used in order to obtain maximum masticating efficiency and tissue tolerance. Some dentists insist that a "cusp" (cuspating) posterior tooth is the tooth of choice, while others are equally adamant in their belief that the nonanatomic (noncuspating) tooth is the tooth of preference. Even among those who prefer a cusp tooth, there is a wide divergence of opinion regarding the cuspal angulation desirable in that tooth. The same is true regarding the type of occlusal pattern which is to be preferred in a nonanatomic tooth. For example, in the selection of a cusp tooth, there is a wide degree of cuspal angulation from which to choose, varying from 20 degrees to 55 degrees. In the noncuspating category, the Hardy, Hall, LaDue, Sears, and other occlusal patterns are available from which to select. In making this selection, sev-

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eral questions arise. Which type should be used? Is there a specific type of tooth which will function better than the others? Will the same type of tooth be desirable for all patients? Are there certain types of mouths or certain types of patients for whom one type tooth will function better than the others? Whenever we undertake the construction of dentures, we are always confronted with the problem of making a choice from the various posterior tooth forms available. At this time, our concepts and techniques and application of tooth forms are empirical. The use of any one tooth form is based upon the unsupported evaluation of the tooth form by the individual using that particular tooth.

## REQUIREMENTS OF TOOTH FORM

It is reasonable to set up certain general conditions which a tooth form must fulfill and to determine what criteria should be applied in determining which tooth form functions best. As prosthodontists, we set up primary and secondary goals. In supplying a patient with dentures, our primary goal is *the preservation of the residual ridges.* The secondary goal is efficiency of mastication and appearance. Tooth efficiency in mastication must always be judged on the basis of its relation to the preservation of the underlying ridges. It is possible to conceive and design a tooth form which will exhibit high masticatory efficiency at the expense of relatively rapid ridge destruction. Conversely, a tooth design may be such that, while its chewing efficiency may be somewhat impaired, it may cause less ridge destruction than other designs. Tooth efficiency during the mastication of food should not be the sole criterion in determining the over-all efficacy of a tooth form. Mastication of food constitutes only one part of the function of dentures. The many hours during which the patient is not masticating food, and yet is making thousands of tooth contacts throughout each 24-hour period, must be considered. These latter more or less lackadaisical tooth contacts are capable of exacting their toll from the underlying tissues.

One of the main difficulties with which we are confronted in complete denture prosthodontics is the scientific evaluation of so-called "basic concepts" or techniques. The need for controlled studies is manifest. Without controlled studies, many of our concepts and techniques will continue to be based on empirical evaluations placed upon them by individuals who are frequently stating opinions and not necessarily facts. This investigation was set up to make a controlled study of various tooth forms.

## COMMON BASES FOR DIFFERENT OCCLUSAL PATTERNS

As in the pilot study,[3] a common base was used for all changes of occlusal patterns. In this manner, the type of impression, its extension, fullness, adaptation, and retention, remain constant throughout the tests.

By having a single base, any changes which might be made on the base would produce the same change throughout the investigation. If a change were made in the base, and the change produced a harmful or undesirable result in the testing of one type of occlusal pattern, the error would be constant for all other occlusal

patterns tested. Construction of the base was such that the entire occlusal pattern could be placed in position or removed from the base with ease and replaced with accuracy.

For the investigation to be valid, the posterior occlusal pattern being tested could be the *only* variable. In order to accomplish this result, a single mounting was used, so the vertical dimension, centric, and eccentric recording were identical. Anterior tooth positions were duplicated by means of plaster index records. While this type of positional duplication cannot be *exact,* it may be considered as well within the limits of reasonable practicability and experimental error. Some discrepancy had to be accepted in the buccolingual, interocclusal, and anteroposterior positioning of the posterior teeth, even though scale measurements were used to duplicate these positions as closely as possible.

Use of the common base in testing posterior tooth patterns differs from the technique used by Payne[4] and McLean,[5] wherein two sets of dentures were constructed for the same patient on duplicate casts but with different occlusal patterns. As was pointed out,[1] any adjustment or change on the denture base of one denture would be almost impossible to duplicate on the other base. This would allow a possibility of error which is eliminated by the use of a common base.

Thompson[6] used a common base with a slotted arrangement for the changing of the posterior tooth form in his study. For testing of posterior occlusal patterns, this arrangement is satisfactory provided that no change in the incisal guide angle is necessary, as would be required when testing a "balanced" and "nonbalanced" occlusion.

Two types of bases were used in the pilot study. In one type, a cast gold base was used to which the occlusal insert could be attached by means of Allen screws. The palatal portion and the borders of the maxillary base were completed in acrylic resin. The same technique was used to complete the borders of the mandibular base. In the other type, cast aluminum bases were used with provision made for the attachment of the occlusal insert by means of Allen screws.

The main objection to these bases was the means of attachment of the occlusal insert. To "line up" the insert and the metal lugs on the base so that the parts could be threaded properly was a difficult and time-consuming task. Also, the inserts had to be changed with extreme care to avoid damaging the threads of the screw attachment.

### DESIGN OF INSERT ATTACHMENT

To overcome the handicaps imposed by the use of a screw attachment, the design of attachment for the occlusal inserts was changed. Complete cast maxillary and mandibular bases were utilized except that provision was made to complete the palatal portion of the maxillary base with acrylic resin. A new method for attachment of the insert to the metal base was designed which was similar to an attachment used by Brill.[7]

"Collar button" lugs were cast on the metal base to provide anchorage. Two pieces of 18-gauge wrought gold wire, which are properly spaced to engage the "collar button" on the cast base, were imbedded in the acrylic resin insert to at-

tach the occlusal insert to the metal base (Fig. 1). At first, three "collar button" or "snap" attachments were used. Later, it was found that one attachment on the right and one on the left, in approximately the first molar region, were adequate for the retention of the insert. This "snap" attachment permitted changes of the inserts to be made rapidly and with little or no danger of distortion of the base or the inserts.

This means of attachment may have a practical application other than the one suggested by Brill. For example, by the use of common base and "snap" attachments, it is possible to supply a patient with two or more inserts which could differ in esthetic appearance and tooth positioning. Optimum positioning of anterior and posterior teeth for increased masticatory efficiency need not necessarily meet the esthetic requirements which the patient may desire at times other than when

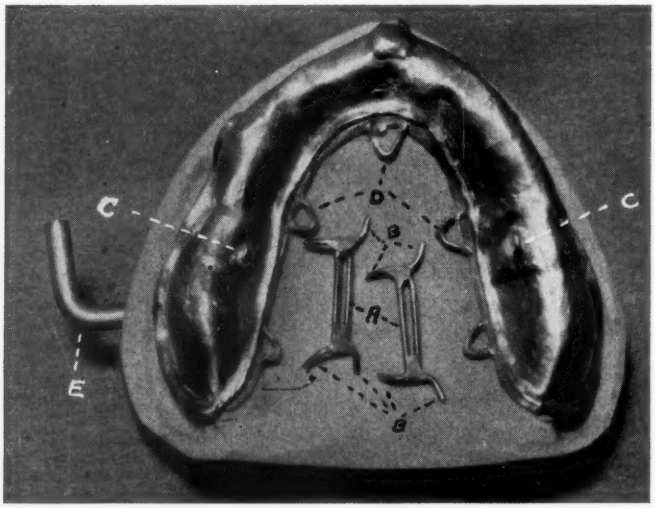


Fig. 1.—The maxillary gold base. *A*, the spaced clips are made of 18-gauge round wire. The space between the wires is sufficient to engage the "collar button" uprights *C*. *B*, the free ends of the spaced "clips" will be imbedded in the acrylic resin insert. *D*, the extension loops from the metal base to engage the acrylic resin palatal portion of the maxillary denture. *E*, the key which attaches the two portions of the split mounting plates.

masticating food. Since the reverse is also true, the possibility is suggested that a patient may be supplied with two sets of inserts, one for appearance and one for mastication.

## TECHNIQUE FOR CONSTRUCTION OF THE ATTACHMENTS

The maxillary and mandibular wax-up for the gold base is completed on the refractory cast, then the locations for the attachments are selected. The male portions of the attachment are waxed parallel to each other and located slightly to the lingual side of the crest of the ridge in approximately the second bicuspid and first molar regions. In instances where there is a close interridge relationship, improper

placement of these "collar button" uprights will make it difficult to position the posterior teeth properly.

The upright or "collar button" part of the attachment is formed so that its greater length lies in an anteroposterior direction so as to offer the least amount

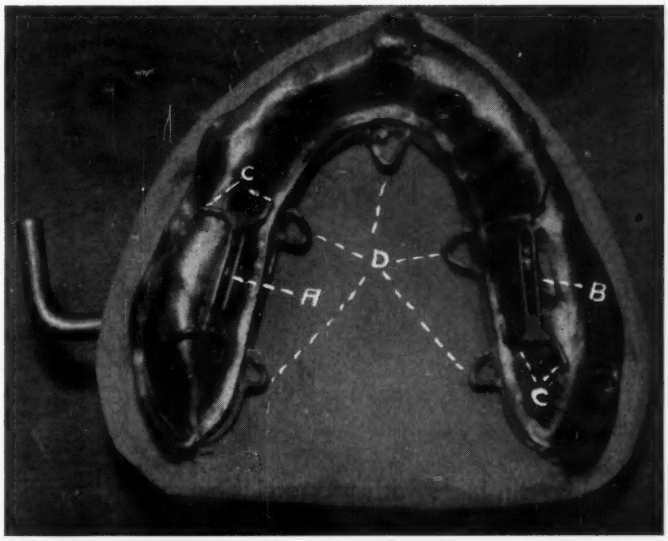


Fig. 2.—*A*, the "collar button" upright on the metal base. *B*, the spaced "clip" engaging the "collar button." *C*, the free ends of the metal clip. *D*, the attachments for the palatal acrylic resin.

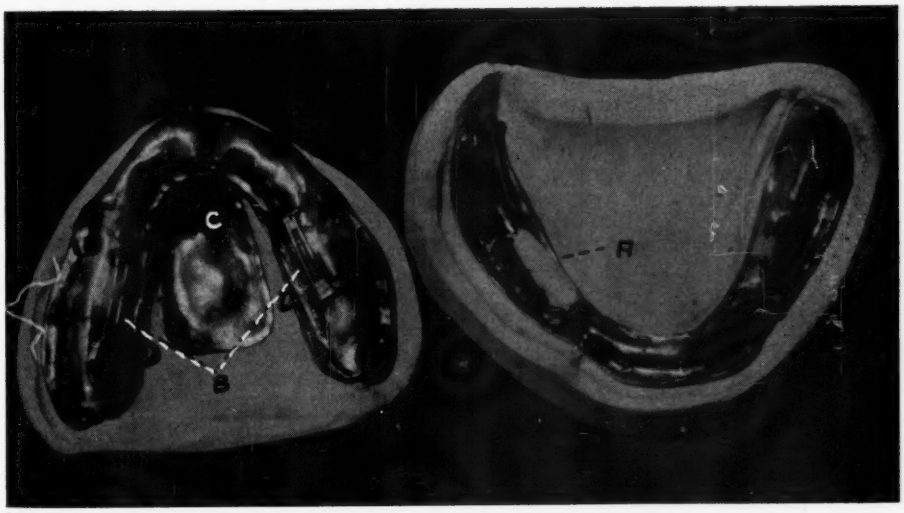


Fig. 3.—*A*, the spaced "clip" and the "collar button" are covered with artificial stone to prevent the adherence of acrylic resin to the functioning parts of the attachment during the processing procedure. The free ends of the clip are not covered. *B*, the spaced "clips" prior to being covered with artificial stone. *C*, the metal relief for the maxillary cast.

of obstruction to the setting of the teeth. The upright needs to be only about 2.5 mm. in height, and it is waxed slightly thicker at the free end to allow the spring of the female portion of the attachment to snap on.

After casting the metal bases, the female portion is formed by soldering together two pieces of 18-gauge wrought gold wire in such a manner that the space between the parallel wires will be sufficient to engage the upright ("collar button") and snap in place. The free ends of the wires are bent slightly to afford better retention into the acrylic resin insert (Fig. 2).

The female portions formed by the two spaced 18-gauge wrought wires are placed in position on the male projections. Both the spacers and projections are covered with a mix of artificial stone to afford protection to these parts during the processing of the acrylic resin. Care must be used to avoid covering the free ends (retention) of the wire which will later be imbedded into the acrylic resin (Fig. 3).

## TECHNIQUE FOR CONSTRUCTION OF THE DENTURES

Impressions of the maxillary and mandibular ridges were made from which the working casts were recovered. Split mounting plates were embedded in the bases of the casts.

Stabilized acrylic resin bases with wax occlusion rims were utilized to secure the preliminary vertical dimension of occlusion and the centric relation record. A posterior palatal seal was made on the maxillary cast.

A face-bow (Hanau Model C) transfer was made, and the maxillary cast was mounted on a Hanau SMX articulator. The mandibular cast was mounted by means of a preliminary wax occlusion rim centric relation record. The casts were mounted at this time to determine the optimum placement of the male projections. An improper placement of these uprights would make it difficult to arrange the teeth properly. A tentative selection of anterior teeth was made at this time.

It was a simple procedure to remove the maxillary and mandibular casts from the articulator mounting because the split plate mounting had been used. The casts were duplicated in a refractory material by the use of a reversible hydrocolloid. The wax patterns for the bases were formed on the refractory casts. Twenty-six gauge sheet wax was used to form the base proper, while the borders were waxed heavier to make a border "roll" and to form an edge for the acrylic resin part of the base to fit against. The upright or "collar button" projections were waxed on, and the bases were cast in gold. The female parts of the attachments were formed, placed in position, and covered with the artificial stone. The assembled attachments were covered with artificial stone to prevent the acrylic resin from coming in contact with them during processing. The casts and metal bases were returned to the articulator, and a tentative set-up of the teeth was made. The palatal portion which was not covered with gold was now covered with wax to aid in the retention of the maxillary base during the final checking of centric relation. The trial dentures were returned to the patient's mouth, and a final check

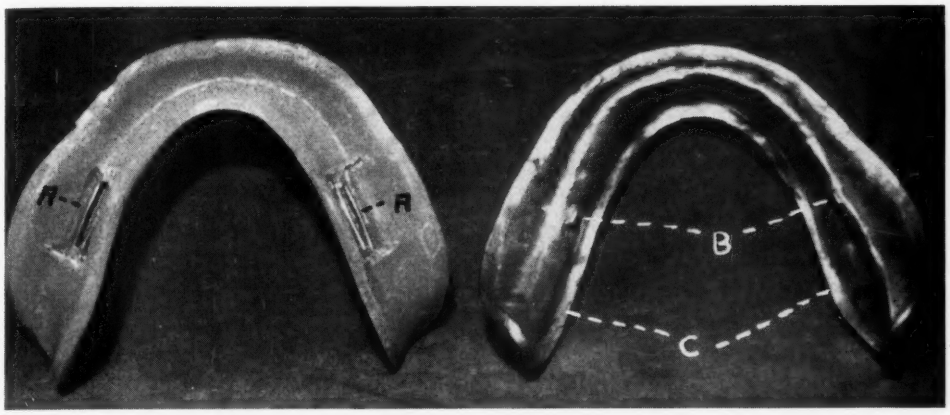


Fig. 4.—The mandibular insert after processing and removal from the metal base. *A*, the protective artificial stone has been removed. *B*, the "collar button" uprights. *C*, a full ledge finish on the metal base is used to avoid a knife-edge finish.

Fig. 5.

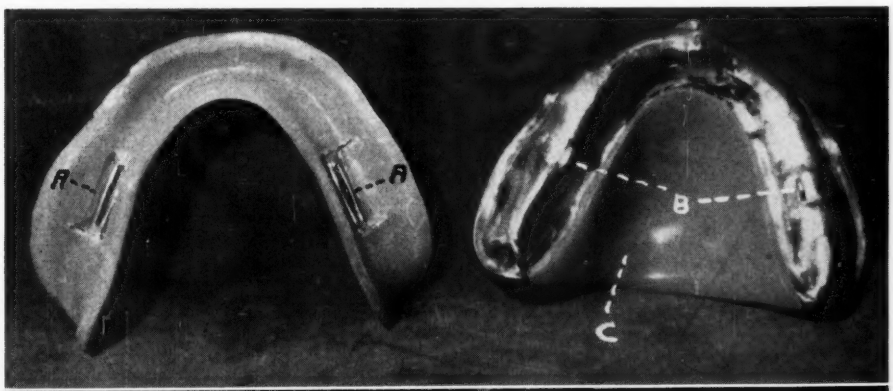


Fig. 6.

Fig. 5.—The palatal portion *C* has been processed and finished in acrylic resin. See Fig. 4.

Fig. 6.—*A*, the tissue surface of the mandibular metal casting. *B*, the palatal surface of the complete maxillary denture base. Note that the palatal portion is finished in acrylic resin.

of vertical dimension and centric relation records was made. Centric relation was verified by means of the interocclusal wax record technique. A protrusive registration was made and transferred to the articulator, and the esthetic requirements were completed.

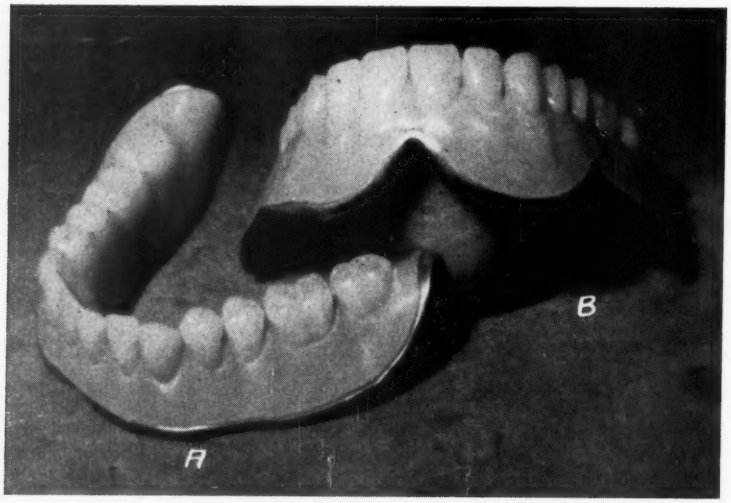


**Fig. 7.**—*A*, the mandibular base with the insert in position. *B*, the maxillary base with the insert in position.

When the trial dentures were returned to the articulator, the posterior teeth were set up into a balanced occlusion. Since more than one insert was to be used, it was necessary to proceed with the processing of the inserts which were waxed onto the metal bases. The palatal portion of the maxillary denture base was not processed at this time. After the inserts were processed and still attached to the metal bases, they were returned to the articulator mounting, and the teeth were spot-ground to eliminate the premature occlusal contacts which were due to inevitable processing errors. A plaster index of the anterior teeth was made at this time. The inserts were removed from the gold bases, and the artificial stone found clinging to the female part of the attachment, which was now embedded in the acrylic resin by means of the free ends of the wires, was carefully cleaned away (Fig. 4).

Another set of female spring wire attachments were constructed and placed in position on the bases as described previously. A new set-up of teeth was made using the plaster index for setting the anterior teeth. The posterior teeth used on the second set of inserts were the second type of teeth to be tested. The processing of the inserts in acrylic resin and the finishing procedure were repeated. Since no other inserts were to be made, the palatal portion of the maxillary base was processed along with the inserts (Figs. 5, 6, and 7).

It will be noted that, within the limits of practicability, all steps in the procedure remained constant, except for the change in the posterior tooth form.

## SELECTION OF SUBJECTS

The criteria for the selection of volunteer patients* were: the probable reliability to continue with the experiment until their part in it was completed; good relative intelligence; adequate interridge space; and a history of previous denture-wearing experience. No selection was made on the basis of the type or condition of the residual ridge. Some had ridges which were soft and flabby, others had ridges which could be classified as normal. The chronologic age of all patients put them in the category of "senior citizens," 55 to 70 years of age. There would obviously be advantages to the use of either experienced or inexperienced denture patients. However, a lack of experience was deemed to be detrimental, because those with no denture experience would have to be permitted varying lengths of time to learn the fundamentals of denture control, by using the lips, cheeks, and tongue, and to adjust to the mental outlook toward the wearing of dentures. Thus, by the time the patient had mastered the use of dentures, he would no longer be classified as inexperienced.

## SELECTION OF TOOTH PATTERNS

One of the perplexing problems was to decide upon the tooth patterns to be tested from the myriad number available. The tooth patterns selected were the 20-degree posterior tooth as representative of an average cuspal angulation of a cuspating tooth, and the Hall's posterior tooth as representative of the noncuspating tooth. The choice of occlusal patterns was limited to two so as not to confuse the patient and to keep the experience with each occlusal pattern well within the memory range of the patient.

The problem also arose as to which type of occlusal pattern should be worn first by the patient. Inasmuch as all the patients selected for the investigation had been wearing dentures with 20-degree posterior teeth, it was decided that the 20-degree posterior tooth inserts should be placed in the mouth first. In this manner, the patient would encounter no great sense of change when going from the "old" dentures to the test dentures.

In the pilot study,[3] changes of inserts were made at 48- to 72-hour cycles. In the present investigation, the time elapsing between changes of the occlusal patterns was increased. The cycle of changes varied from 3 to 4 days up to 2 and 3 weeks. There were two reasons for this change: (1) to afford a better opportunity to determine which insert was responsible for mucosal changes if they occurred, and (2) to give the patient an opportunity to make more mature observations of the teeth being tested.

## PATIENT REACTION AND COMMENTS

Patient reaction to the investigation must receive evaluation. With rare exception, most patients will react to the spirit of the investigation as well as to

*Domiciliary patients of the Veterans Administration Center, Bay Pines, Fla.

the personality of the investigator. It was explained carefully to the patients that whatever report they wished to make was entirely acceptable and that the investigator was totally disinterested, from a personal standpoint, as to what their subjective reactions might be regarding their experiences during the tests. Nevertheless, it became necessary to repeat this caution from time to time, as it was noted that the patient would try to answer questions which *he thought would please the investigator*. Questions regarding patients' reactions were asked in such a manner as to minimize the possibility of asking leading questions.

Not infrequently, the subjective responses were totally at odds with the objective findings. For example, the question might be asked: "Do these dentures cause you any pain?" The patient might answer "'No," but careful examination would reveal areas of irritation and even well-defined ulceration. When this was called to the patient's attention, he might reply, "Well, it doesn't hurt much," or "It doesn't hurt enough to complain about." It could be assumed that, in this respect, the individual threshold of sensitivity would play a part, for the reverse was also observed; namely, complaint of a great deal of soreness which could not be localized objectively by an area of irritation or ulceration. During the investigation, the evaluation of subjective and objective symptoms was made on the basis that, whenever possible, subjective symptoms had to be substantiated by objective symptoms.

CASE 1.—McL. The mandibular ridge was narrow and somewhat V-shaped with a definite slope toward the lingual. The maxillary arch was small with low-hanging, slightly undercut tuberosities. The maxillary anterior ridge from the right first premolar to the left first premolar area was extremely soft and flabby.

*Subjective.*—The patient preferred the 20-degree posterior tooth insert for the mastication of food, but was more comfortable with the Hall posterior tooth insert at other times. Typical comments regarding Hall's posterior teeth were: "Comfortable but I could not chew with them"; while regarding the 20-degree posterior teeth, "satisfactory," "no trouble," "penetrate food easily."

*Objective.*—Neither type of tooth produced notable irritation. The patient preferred the 20-degree posterior tooth insert.

CASE 2.—M.I.N. The mandibular arch was somewhat narrow and relatively high. The tissue from the right-to-left cuspid region was soft and easily displaceable. The ridges of the maxillary arch were rather full but with easily displaceable tissue extending from the right to the left cuspid region.

*Subjective.*—Typical comments by the patient were: "The molar teeth in this set (Hall's) are much better than the others (20-degree posteriors)." "They (Hall's) seem to permit me to grind easier than with the others (20-degree posteriors)." As the study continued the patient voiced the following opinion: "The upper denture (Hall's) seems to fit somewhat tighter, but to cause more soreness." "These teeth (Hall's) always make my mouth a little more sore than do the others (20-degree posteriors), but I prefer these dentures (with Hall's) so far as the molars are concerned."

*Objective.*—The Hall's posterior teeth caused a greater amount of irritation than did the 20-degree posterior teeth. However, there was no doubt in the patient's mind for his preference for the inserts with the Hall's posterior teeth.

CASE 3.—H.I.L. The mandibular ridge was narrow and V-shaped with a lingual undercut extending from the lower left first premolar to the retromolar pad. The soft tissue covering the ridge was easily displaceable. The maxillary arch was rather small and covered with extremely soft and flabby tissue.

*Subjective.*—This patient's estimate of the dentures vacillated considerably. During one period of testing with the 20-degree posterior teeth, he stated, "Chewing food excellent," "the lowers bind slightly." Regarding Hall's posterior teeth, "The teeth feel like I am bucking nature," "The teeth are dull," "However, the lower seems to sit down lower on the ridge." The patient's reports continued to be contradictory; however, while near the end of the test he stated a preference for the 20-degree posterior teeth, it was not without the qualification, "However, this lower denture (Hall's posterior teeth) stays in place better."

*Objective.*—It was judged that either type of posterior tooth caused an equal amount of soreness and probably for the same reason, that is, a fault in the denture base. After the denture bases were corrected, the patient developed no irritation of any consequence with either set of posterior teeth.

CASE 4.—McG. The mandibular arch was of average size and flat. The maxillary arch was of average size with soft, flabby tissue extending from the right premolar to the left premolar region.

*Subjective.*—Regarding the Hall's posterior teeth the patient stated, "These are the teeth, they chew better and feel better than the others (20-degree posteriors)." However, when the 20-degree posterior teeth were substituted for the Hall's teeth and the patient was allowed to use them, the patient stated, "These are the teeth—I can do anything with them." It would thus appear that the patient had no preference for one type of posterior tooth over the other.

*Objective.*—During the test with this patient, it became advisable to recheck the occlusion and correct an occlusal disharmony. After correction of the occlusion, it was found that the Hall's posterior teeth seem to cause slightly more soreness on the lingual surface of the mandibular ridge than did the 20-degree teeth. Relief was made for these sore areas which appeared when the patient wore the Hall's posterior teeth. After these adjustments, the patient had no particular preference for one type of posterior tooth over the other.

CASE 5.—McD. Both arches were rather broad and wide and had well-formed ridges.

*Subjective.*—During the initial period of testing, the patient stated with reference to the Hall posterior teeth, "Best dentures I ever had." During a later test period the patient stated with reference to the 20-degree posterior teeth, "These dentures feel wonderful." During later testing, the patient continued to find no essential difference between either type of posterior tooth form, but did imply that the Hall's teeth were more comfortable when *not* chewing.

*Objective.*—After initial correction of border soreness, the patient tolerated both types of posterior teeth equally well. As was indicated, the patient had no special preference for one or the other posterior tooth form. It did seem, however, that the Hall's posterior teeth caused slightly more irritation than did the 20-degree teeth.

CASE 6.—C.A.R. The residual mandibular ridge was narrow, somewhat V-shaped, and sloped toward the lingual. The tissue was movable and easily displaceable from the lower left cuspid region to the retromolar pad. The maxillary arch was small with low-hanging, slightly undercut tuberosities. Soft, flabby tissue extended from the first premolar on the right side to the first premolar on the left side.

*Subjective.*—"It is difficult to determine any great difference," "My first impression was a feeling of lighter weight with the second set (Hall's), but this wore off as time went on." However, "Managing in chewing and swallowing was easier, but I had sensation of tingling in the chin when biting" (nerve impingement?). Also, "Teeth (Hall's) seemed to bite the cheeks on both sides and move when eating." Again, regarding the 20-degree teeth, "I have a better security of having the lower plate stay in place."

*Objective.*—The patient showed a slight preference for the Hall's posterior teeth despite a statement of having "better security" with the 20-degree posterior teeth. Hall's teeth seemed to produce slightly more soreness than the 20-degree teeth.

CASE 7.— D.I.L. The mandibular ridge was of average size and covered with easily displaceable tissue. The maxillary arch was of average size. The tuberosities were rather prominent. Soft, flabby tissue extended from the right cuspid to the left cuspid region.

*Subjective.*—The patient at first seemed to prefer the Hall's posterior teeth commenting that, "They grind much easier than the other teeth (20-degree posterior teeth)," "They are perfect grinders," and "These teeth are smoother." About 3 weeks later, the patient commented that on further reflection, "The 20-degree teeth seem to cut faster and I like them better. Chewing is pretty good with both (20-degree and Hall's posterior teeth), but I prefer the 20-degree posterior teeth."

*Objective.*—The Hall's posterior teeth seemed to produce more irritation than did the 20-degree teeth. The fact that the smoothness of the Hall's teeth was worthy of comment by the patient is significant, as is the fact that the final preference was for the 20-degree teeth because they "cut faster."

CASE 8.—G.I.L. The mandibular arch was small. The residual ridge was high and knife-edged. The maxillary arch was small with a rather narrow parallel-sided residual ridge.

*Subjective.*—The patient at first preferred the Hall's posterior teeth, stating that, "These (Hall's teeth) feel better than the others, but chewing is about the same (as with the 20-degree posterior teeth)." Later, the patient was equally sure that he liked the 20-degree posterior teeth better than the Hall's posterior teeth, and stated that he could "eat better with these (20-degree teeth)."

*Objective.*—Slightly more soreness was discernible while the patient was using the 20-degree teeth than with the Hall's teeth. His preference for the 20-degree posterior teeth was obviously based on the fact that he felt he could "eat better" with the 20-degree teeth than he could with the Hall's teeth.

## SUMMARY OF TOOTH PREFERENCE

A résumé of tooth preference does not indicate a clear-cut preference for either

type of posterior tooth. The slight edge in preference of the 20-degree tooth could be attributed to experimental error in evaluation.

Preferences as stated were: (1) 4 patients preferred the 20-degree posterior teeth, (2) 1 patient preferred the 20-degree posteriors with qualification, (3) 1 patient preferred the Hall's posterior teeth, and (4) 2 patients had no particular preference for either the 20-degree or Hall's posterior teeth.

### CHEWING TESTS

Chewing tests were made with freshly roasted peanuts and carrots. These foods were selected because they are not readily disintegrated into fine particles during mastication.

The carrots were cut into approximately ⅜ inch squares. No attempt was made to dictate to the patients the number of squares which they were to attempt to chew on each trial. The objective was to allow the patient free choice of the size of the bolus to be chewed on the premise that their past experience would guide them in their selection. The same principle was adopted when the patient was given the roasted peanuts for the mastication tests.

It was suggested to the patients that they chew on one or both sides or in any manner which seemed most comfortable to them. The number of masticatory strokes the patient was to be permitted was first determined by having them chew several test boluses of food. The average number of strokes the patient made up to the time of deglutition of the food was counted and averaged. This average was noted for each patient tested, and this was the number of strokes permitted. As in the pilot study, approximately the same number of chewing strokes was used, whether the patient was chewing carrots or peanuts.

A 100-mesh screen was used for a sieve to study remaining particle size and weight changes in the test materials after mastication by the patient.

Considerable caution must be used in the evaluation of the results of chewing tests. Indeed, their value as a scientific measurement is doubtful. Several factors must be evaluated:

1. Weight tests are usually made to indicate the *amount* of maceration of food which has occurred and will pass through a 100-mesh sieve. If the test is conducted with 5 Gm. of carrots, the amount recovered after passing the bolus through the 100-mesh screen would exceed that of the original 5 Gm. despite the fact that much of the material had passed through the sieve. The reason, of course, is obvious. During the process of mastication, the food particles would be broken up into relatively small particles which would become thoroughly insalivated. The weight of the incorporated or adherent saliva would account for the increase in weight.

The roasted peanuts permitted a slightly better index of the *amount* of weight change. As indicated, fresh roasted peanuts were used in the test and presumably were fairly free of moisture. After the chewing tests, the remaining bolus (that which failed to pass through the 100-mesh per square inch sieve) was dried by heating for 10 minutes in an oven of 350° F. and then reweighed. The accuracy of this technique is questionable, although the same inherent difficulty may be expected to occur, regardless of the type of food being utilized for a test bolus.

2. A particle-size test is made to indicate the *degree* of maceration of the food which occurs, and as with the weight test it is offered as an indication of tooth efficiency. Here again, this form of testing leaves much to be desired. The resultant particle size will depend upon several modifying factors. The vigor with which the patient attacks the bolus of food at the specific time the test is conducted is an important factor. If the patient is in a lackadaisical mood, it may be expected that the attack on the bolus will be less vigorous than if the patient were feeling more determined in his approach. While fixing the number of masticatory strokes will tend to overcome this factor, nevertheless, it does not form a reliable solution. On occasion, the patient may allow a relatively large morsel of food to slip out of the control of the lips, tongue, and cheek action. If this morsel falls into a space where the patient finds it somewhat difficult to dislodge, it would not be rebalanced on the teeth to permit further reduction within the allotted number of masticatory strokes.

## RESULTS OF CHEWING TESTS

Tooth efficiency as indicated by the percentage of the bolus of peanuts passing through a 100-mesh sieve is seen in Table I.

TABLE I. COMPARISON OF TOOTH EFFICIENCY

| PATIENT | TYPE OF POSTERIOR TOOTH | WEIGHT OF PEANUTS CHEWED (GM.) | WEIGHT OF PEANUTS RECOVERED (GM.) | WEIGHT OF PEANUTS PASSING THROUGH 100-MESH SCREEN (GM.) | PER CENT PASSING THROUGH SCREEN |
|---|---|---|---|---|---|
| Case 1 McL. | Hall's | 3.12 | 1.89 | 1.23 | 39.4 |
| | 20-degree | 3.12 | 1.43 | 1.69 | 54.1 |
| Case 2 M.I.N. | Hall's | 3.12 | 2.015 | 1.1 | 35.2 |
| | 20-degree | 3.12 | 1.3 | 1.82 | 58.3 |
| Case 3 H.I.L. | Hall's | 5.0 | 3.37 | 1.63 | 32.6 |
| | 20-degree | 5.0 | 2.0 | 3.0 | 60.0 |
| Case 4 McG. | Hall's | 5.0 | 1.57 | 3.43 | 68.6 |
| | 20-degree | 5.0 | 1.41 | 3.59 | 71.8 |
| Case 5 McD. | Hall's | 3.12 | 1.95 | 1.17 | 37.5 |
| | 20-degree | 3.12 | 1.20 | 1.92 | 61.5 |
| Case 6 C.A.R. | Hall's | 3.12 | 1.56 | 1.56 | 50.0 |
| | 20-degree | 3.12 | 1.04 | 2.08 | 66.6 |
| Case 7 D.I.L. | Hall's | 5.0 | 1.1 | 3.9 | 78.0 |
| | 20-degree | 5.0 | .81 | 4.09 | 81.8 |
| Case 8 G.I.L. | Hall's | 5.0 | 1.5 | 3.5 | 70.0 |
| | 20-degree | 4.11 | 1.16 | 2.95 | 59.0 |

From Table I it may be observed that with the exception of Case 8 the 20-degree posterior teeth proved to be more efficient than the Hall's posterior teeth

when judged by the weight of the amount of the peanuts which passed through the 100-mesh sieve.

### FINENESS OF CHEW

A number of observers not connected with the investigation were asked to evaluate the relative fineness of the residual chew of both the peanuts and carrots. The results of these observations are seen in Table II.

TABLE II. FINENESS OF CHEW

PEANUTS

| CASE | NUMBER OF OBSERVERS | 20-DEGREE POSTERIORS FINER | HALL'S POSTERIORS FINER | SAME FINENESS |
|---|---|---|---|---|
| 1 | 5 | 5 | | |
| 2 | 5 | 5 | | |
| 3 | 4 | 3 | 1 | |
| 4 | 5 | 4 | 1 | |
| 5 | 5 | 5 | | |
| 6 | 5 | 3 | 1 | 1 |
| 7 | 5 | 5 | | |
| 8 | 5 | 5 | | |

CARROTS

| | | | | |
|---|---|---|---|---|
| 1 | 5 | 3 | 2 | |
| 2 | 5 | 5 | | |
| 3 | 5 | 4 | 1 | |
| 4 | 5 | 5 | | |
| 5 | 5 | 1 | 1 | 3 |
| 6 | 5 | 0 | 4 | 1 |
| 7 | 5 | 5 | | |
| 8 | 5 | 5 | | |

### CORRELATION OF DATA

An analysis was made of the relationship of the form and type and condition with the chewing findings as listed in Tables I and II, and the patients' subjective reactions as to choice of posterior tooth form. Six of the patients had a ridge type and form which might be classified as "not favorable," and only 2 patients had a ridge type and form which could be classified as "favorable." Of the 6 patients (Cases 1, 2, 3, 6, 7, and 8) with the "not favorable" ridge form and type, 1 (Case 2) preferred the Hall's teeth despite the greater efficiency of the 20-degree posterior teeth as revealed by the chewing tests. For 1 patient (Case 8), who preferred the 20-degree posterior teeth, the chewing tests revealed that the Hall's

posterior teeth were 11 per cent more efficient in the screen test for peanuts, while the fineness of chew tests revealed that the 20-degree posterior teeth were more efficient.

The 2 patients (Cases 4 and 5) with a "favorable" ridge type and form had no special preference for either the 20-degree or Hall's posterior teeth, but the screen tests indicated that the 20-degree posterior teeth were more efficient (Case 4, 3.2 per cent and Case 5, 24 per cent). When the fineness of chew of peanuts and carrots for Case 4 was judged, the 20-degree posterior teeth were considered to be more efficient. However, with Case 5, it was found that the 20-degree posterior teeth produced a finer chew with peanuts but not with carrots.

## SUMMARY

1. Test denture bases with interchangeable inserts with two types of posterior teeth were made. Subjective observations of the 8 patients were recorded along with objective observations, chewing efficiency tests, and a correlation with the ridge conditions.

2. The subjective responses of the patients indicated that there was a greater preference for the 20-degree posterior teeth than for the Hall's posterior teeth. This greater preference was stated probably because of the greater ease with which the patients felt they could masticate the food. While the formal chewing tests were limited to the use of two foods (peanuts and carrots), the basis for the preference made by the patients was on their experience with the total diet with which they were supplied during their three regular daily meals.

3. A substantial number of the patients liked the "feel" of the Hall's posterior teeth even though their final choice was the 20-degree posterior teeth.

4. The Hall's posterior teeth produced more soreness during the adjustment period than did the 20-degree posterior teeth.

5. The 20-degree posterior teeth showed a definite indication of greater efficiency when chewing peanuts. The difference in fineness produced by the 20-degree posterior teeth and the Hall's posterior teeth was not quite so well defined when chewing carrots. This indicates that, with certain types of foods, the relative chewing efficiency of any one tooth form varies. When the entire diet was considered and the patients' subjective reactions were considered, the 20-degree posterior teeth had a greater over-all efficiency.

## CONCLUSIONS

1. The relatively greater efficiency of the 20-degree posterior teeth during mastication indicates that sharpness of the occluding or masticating surfaces was the determining factor, and probably the reason for the greater number of patients who preferred this type of tooth.

2. The fact that the Hall's posterior teeth felt better to a significant number of the patients at times other than when they were engaged in the mastication of food, and even though the Hall's posterior teeth were not their final choice, it indicates that the relative smoothness of the occluding surfaces was probably the responsible factor.

3. The greater amount of soreness produced by the Hall's posterior teeth indicates that the more blunt surfaces and lack of spillways in the Hall's teeth necessitated the exertion of a greater amount of force by the patient, not only to penetrate the bolus of food but also during the shearing action to reduce the bolus size.

4. These findings considered together would indicate that posterior teeth should have (a) sharpness, but not necessarily the sharpness provided by cusps, and (b) relative smoothness during contact, so as to avoid "locking" and "roughness" of the teeth.

5. It is significant that all the patients who showed a preference for the 20-degree posterior teeth had ridges which were classified as "unfavorable" (V-shaped, small arches, soft, flabby, easily displaceable tissue, etc.). Here again, the preference may be attributed to the relatively greater ease of mastication because of the relative sharpness of the teeth.

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3900 Central Ave.
St. Petersburg 11, Fla.

# FACTORS AFFECTING THE SETTING OF ZINC OXIDE-EUGENOL IMPRESSION PASTES

DIORACY FONTERRADA VIEIRA, L.D.*
*São Paulo, Brazil*

WITH THE EXCEPTION OF a few published investigations,[1-4] little information appears in the literature concerning the factors which affect the setting time of the zinc oxide-eugenol impression pastes.

Ross[1] states that the temperature at which he worked was such that at its highest point it retarded solidification. Up to a point, this was contrary to experiments undertaken by Skinner and his collaborators,[2] although they had verified the action of two agents at the same time (humidity and temperature). Wallace and Hansen[3] concluded that humidity is a positive factor in the acceleration of setting time.

Because of the rapid growth in the use of these pastes, the little that is known of their properties, the necessity for the rigorous control of their setting time, and the lack of complete data with regard to the factors affecting their setting time, a study of the factors that influence the setting time of zinc oxide and eugenol pastes was made.

## MATERIALS INVESTIGATED

Five zinc oxide and eugenol impression pastes, purchased in the open market, were studied. These pastes are listed in Table I with the name of the manufacturer and the form in which they are dispensed. Each paste is designated by a code letter.

The materials were in two forms: (1) powder and liquid (paste *E*), the powder presumably containing essentially zinc oxide and rosin and the liquid content being eugenol and rosin, and (2) two pastes, the essential ingredients being the same except extended to paste form. Hereafter, these will be referred to as zinc oxide paste and eugenol paste.

The components, naturally, are not only zinc oxide and rosin or eugenol and rosin, but are also made up of other materials such as accelerating substances, retarding substances, binder substances, and substances that give more smoothness to the paste.

Each of the materials used was taken from the same lot, and the manufacturers' instructions were followed so long as the controlling factors did not need modification.

For each group of experiments in which only one factor was varied, at least three tests were made. If there were great discrepancies among the results of each

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*Assistente da Cadeira de Metalurgia e Quimica Aplicadas, da Faculdade de Farmácia e Odontologia da Universidade de São Paulo.

group, a new series of tests was undertaken so that there would be no doubt as to the final result in each group. Each setting time (last two columns in all tables) represents an average of at least three tests.

TABLE I. MATERIALS INVESTIGATED

| CODE LETTER | TRADE NAME | MANUFACTURER | DISPENSED FORM |
|---|---|---|---|
| A | S.S.W. impression paste | The S.S. White Dental Mfg. Co. (Philadelphia) United States | Pastes (2) |
| B | Kelly's impression paste improved | Kelly-Burroughs Laboratory, Inc., (Pittsburgh) United States | Pastes (2) |
| C | Kerr impression paste | Kerr Mfg. Co. (Michigan) United States | Pastes (2) |
| D | Pasta Barbosa | Ind. Dental Barbosa (São Paulo, Brazil) | Pastes (2) |
| E | Ackerman impression cement (fast liquid) | The Ackerman Dental Mfg. Co. (California) United States | Powder + Liquid |

METHODS

The Vicat needle[5,6] was chosen to determine the setting time.

The procedure, except when dealing with *E*, was as follows: The material was carefully weighed and mixed for a fixed period with a stainless steel cement spatula on waterproof, nonabsorbent paper. For *E*, the powder was weighed and the liquid measured with a Luer type syringe (this was used because the liquid was excessively viscous), and the mixing was accomplished on a glass slab. The paste obtained was put into a cylindrical metal ring 1.7 cm. in diameter and 0.8 cm. in height which was set upon a glass slab placed at the base of the Vicat apparatus. The blade of the spatula was pushed at an angle of 45 degrees across the upper edge of the ring, and as this blade planed the paste, it cleared what was in excess, leaving at the same time a smooth surface that was parallel to the base of the glass slab. Then, the determination of the setting time was started with the reading of the scale of the apparatus at one-minute intervals until final setting had occurred.

After the filled metal ring was placed on a glass slab beneath the Vicat needle, the needle was allowed to penetrate through the paste to the bottom and to rest on the glass slab. The reading of the pointer was noted. The procedure was repeated until the first hardening of the paste was evidenced by the fact that the needle no longer penetrated to the bottom. The time at which this occurred, measured from the beginning of spatulation, was called the *initial setting time*. The *final setting time* was measured in the same manner used by Skinner, Cooper, and Ziehm,[2] that is, the elapsed time from the beginning of spatulation when no penetration of the needle first occurred.

The time at which the paste lost its tackiness or stickiness was also noted.

For all experiments, only one factor was varied at a time, so that factor could be determined as solely responsible for changes in the setting time.

We consider the initial setting time to be very important. Skinner and associates[2] thought of this time as the time "for manipulation," that is, as the time for preparing the material, putting it on the tray, and inserting it in the mouth. In other words, the initial setting time occurs after the paste has contacted the surface to be impressed. After the initial set, the material is not fluid enough to permit the development of an exact mold.

INFLUENCE OF THE ZINC OXIDE/EUGENOL RATIO

All of the variables were held constant throughout this series of experiments except the zine oxide/eugenol ratio.

TABLE II. INFLUENCE OF ZINC OXIDE/EUGENOL RATIO

| MATERIAL | ZINC OXIDE/ EUGENOL RATIO (GM./GM.) | TEMPERATURE (°C.) | TIME (MIN.) | | | |
|---|---|---|---|---|---|---|
| | | | SPATULATION | LACK OF STICKINESS | SETTING | |
| | | | | | INITIAL | FINAL |
| A | 1:2 | 21 | 1′ | 40′–41′ | 31′40″ | 43′8″ |
| A | 3:2 | 20 | 1′ | 21′–29′ | 17′ | 28′ |
| A | 5:2 | 20.3 | 1′ | 20′–30′ | 13′20″ | 22′18″ |
| B | 2:5 | 22 | 1′ | 7′–9′ | 9′ | 19′ |
| B | 3:2 | 22 | 1′ | 4′–8′ | 5′40″ | 14′ |
| B | 5:2 | 21 | 1′ | 4′–7′ | 5′20″ | 13′ |
| C | 1:2 | 21 | 1′ | 4′–6′ | 4′30″ | 10′30″ |
| C | 3:2 | 21 | 1′ | 6′–7′ | 5′30″ | 12′30″ |
| C | 5:2 | 21 | 1′ | 11′–12′ | 11′ | 18′ |
| D | 1:2 | 21 | 1′ | 10′ | 13′ | 26′ |
| D | 3:2 | 21 | 1′ | 6′ | 6′ | 14′ |
| D | 5:2 (Gm./cm.$^3$) | 21 | 1′ | 5′ | 4′ | 9′ |
| E | 2:4 | 23 | 1′15″ | 5′–6′ | 5′ | 13′20″ |
| E | 2:3 | 22 | 1′15″ | 5′–6′ | 6′ | 11′40″ |
| E | 2:2 | 22 | 1′15″ | 4′–5′ | 6′40″ | 10′ |

Except for material *C*, as the quantity of paste or powder containing zinc oxide is increased in relation to the quantity of paste or liquid containing the eugenol, the final setting time is reduced (Table II). The explanation of the opposite result with *C* is due perhaps to the existence of accelerating substances in the paste containing the eugenol instead of being incorporated in the zinc oxide as in the other products. This was verified by the manufacturer. As the quantity of zinc oxide paste is increased, which condition means a proportionate decrease in the quantity of accelerator, the paste takes more time to solidify.

It was noted also that there is an inverse relationship between the increase in quantity of zinc oxide paste and the initial setting time. In other words, as the quantity of zinc oxide paste is increased, the initial setting time is reduced.

The moment at which the stickiness of the material ends does not coincide with the final setting time. Therefore, the fact that this material loses its stickiness should not be considered as the right moment to remove the impression from the oral cavity. For all the materials in paste form, with the exception of *A*, a zinc ox-

ide/eugenol ratio of 3:2 seemed satisfactory for clinical work (for paste *A*, the optimum proportion was 5:2). A zinc oxide/eugenol ratio of 2:2 (Gm./cm.$^3$) is, for *E*, a favorable proportion.

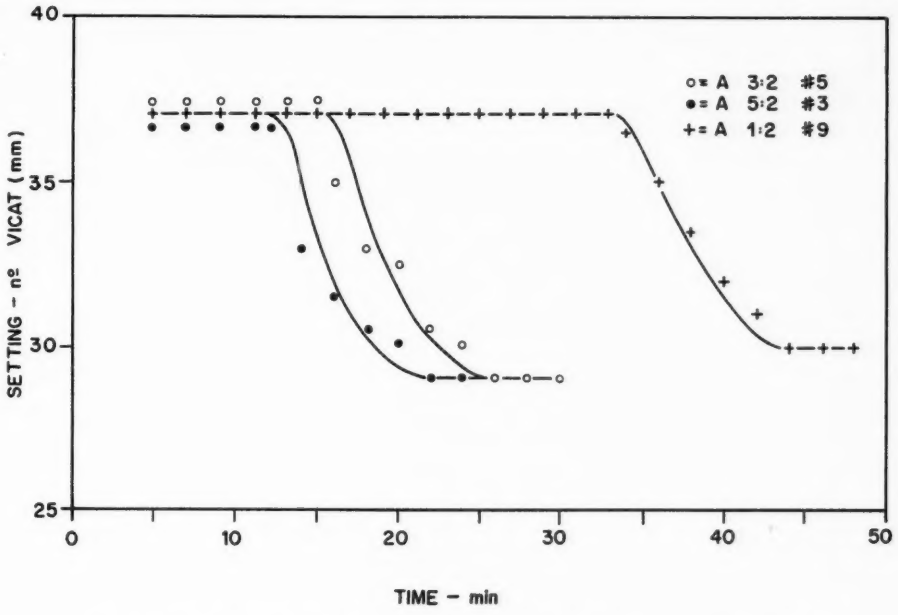


Fig. 1.—The influence of the zinc oxide/eugenol ratio for impression pastes *A*.

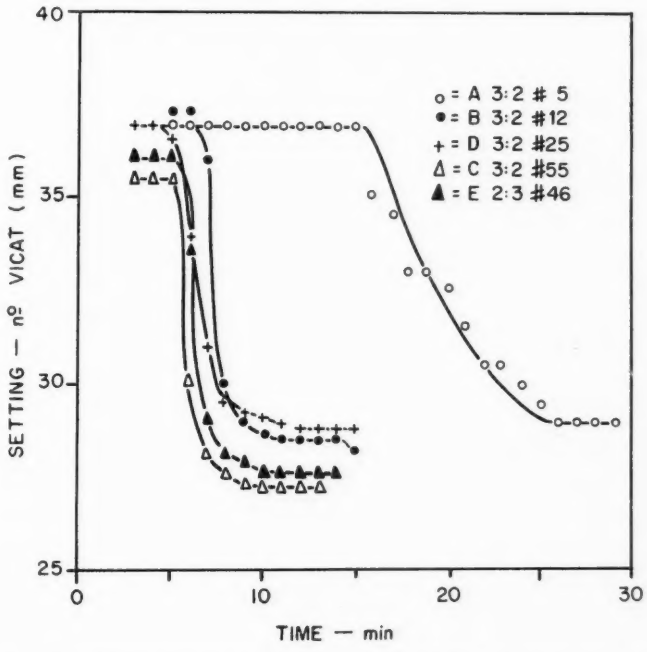


Fig. 2.—The setting times for all pastes studied under the same conditions.

The variation of the setting time in relation to the zinc oxide/eugenol ratio for material *A* is shown in Fig. 1. We see also that the time from the beginning until the end of the setting time is roughly equal for all the proportions. The speed of setting time (Skinner and associates[2]) seems, therefore, to be practically the same.

The behavior of the various materials under the same conditions in relation to setting time is seen in Fig. 2. All of these materials behave in the same way, that is, they have almost the same final and initial setting time, with the exception of *A*, whose action is quite different because of its being very plastic in the proportions which were used for this comparison.

### INFLUENCE OF SPATULATION TIME

The only factor varied in the course of these tests was the spatulation time. Each of the materials was mixed for 2 minutes, 1 minute, and for 30 seconds.

The results of these tests are shown in Table III. Columns 4, 6, and 7 indicate the action of spatulation time in relation to the initial and final setting time. A re-

TABLE III. INFLUENCE OF SPATULATION TIME

| MATERIAL | ZINC OXIDE/ EUGENOL RATIO (GM./GM.) | TEMPERATURE (°C.) | TIME (MIN.) | | | |
|---|---|---|---|---|---|---|
| | | | SPATULATION | LACK OF STICKINESS | SETTING | |
| | | | | | INITIAL | FINAL |
| A | 5:2 | 21 | 30″ | 19′–20′ | 13′ | 26′20″ |
| A | 5:2 | 20 | 1′ | 20′–21′ | 13′20″ | 22′18″ |
| A | 5:2 | 21 | 2′ | 15′–19′ | 12′ | 20′40″ |
| B | 5:2 | 22 | 30″ | 4′–5′ | 5′20″ | 14′ |
| B | 5:2 | 21 | 1′ | 4′–7′ | 5′20″ | 13′ |
| B | 5:2 | 22 | 2′ | 3′–6′ | 5′20″ | 12′20″ |
| C | 3:2 | 19 | 30″ | 6′ | 5′ | 11′ |
| C | 3:2 | 21 | 1′ | 6′–7′ | 5′30″ | 12′30″ |
| C | 3:2 | 19 | 2′ | 4′ | 4′ | 7′ |
| D | 5:2 | 20 | 30″ | 7′–10′ | 6′20″ | 12′40″ |
| D | 5:2 | 21 | 1′ | 5′ | 4′ | 9′ |
| D | 5:2 (Gm./cm.$^3$) | 20 | 2′ | 5′–7′ | 5′ | 9′20″ |
| E | 2:3 | 19 | 30″ | 7′ | 8′ | 16′ |
| E | 2:3 | 22 | 1′15″ | 5′–6′ | 6′ | 11′40″ |
| E | 2:3 | 19 | 2′ | 6′ | 6′ | 11′ |

duction in the final setting time is noted as the spatulation time is increased, and the relationship varies inversely between the mixing time and the initial setting time.

The small discrepancies between some results, principally those from tests in which pastes were spatulated for 1 minute, are due perhaps to small differences in temperature and to conditions inherent in 1-minute spatulation as opposed to 2-minute spatulation and 30-second spatulation. However, if we compare the results of the experiments made in 30 seconds and in 2 minutes (Table III), we see that this relation between mixing time and setting time is inverse.

Although there is also a contrary relation between the termination of stickiness during the experiments and the spatulation time, this lack of stickiness occurs before final setting time.

In Fig. 3, the setting curves of material *B* are plotted for the spatulation times as specified. The aforementioned facts are also observed here; the period of time from the initial setting time to the final setting time is lengthened significantly when spatulation time is varied. The speed of solidification is thus affected by variation in the mixing time.

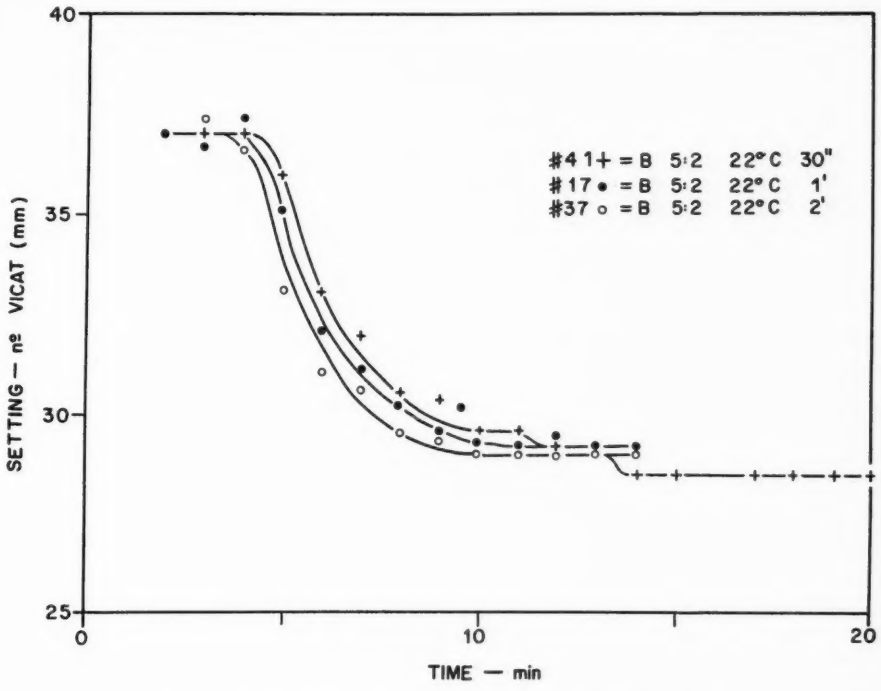


Fig. 3.—The influence of spatulation time on impression paste *B*.

## INFLUENCE OF TEMPERATURE

All factors during these experiments were constant, with the exception of temperature. The temperatures in each group of experiments were as follows: 46°-47° C., 36.5°-39° C., 20°-22° C., and 6°-11° C.

The influence of temperature change is seen in the results given in Table IV. There is a direct relation between increased temperature and the speed of setting time. As the temperature is raised, both the initial and final setting times are diminished.

The significant fact that a material spatulated at room temperature sets at a higher temperature when it is in the mouth indicates that the dentist who is preparing a determined quantity of paste will have enough working time. This working time is reduced, however, by the accelerated setting time of the paste caused by the higher temperature of the patient's mouth.

The relationship between the increased temperature and the time in which the material remains sticky is also inverse. However, it should be noted that the material loses its stickiness quite some time before final setting time and soon after initial setting time.

TABLE IV. INFLUENCE OF TEMPERATURE

| MATERIAL | ZINC OXIDE/ EUGENOL RATIO (GM./GM.) | TEMPERATURE (°C.) | TIME (MIN.) | | | |
|---|---|---|---|---|---|---|
| | | | SPATULATION | LACK OF STICKINESS | SETTING | |
| | | | | | INITIAL | FINAL |
| A | 5:2 | 47 | 1′ | 5′ | 7′ | 12′ |
| A | 5:2 | 37.5 | 1′ | 5′ | 7′ | 13′ |
| A | 5:2 | 20.3 | 1′ | 21′ | 31′ | 22′18″ |
| A | 5:2 | 8.5 | 1′ | ——— | 30′ | 45′ |
| B | 5:2 | 46.7 | 1′ | 3′ | 4′ | 8′ |
| B | 5:2 | 36.9 | 1′ | 3′–4′ | 4′ | 9′ |
| B | 5:2 | 21 | 1′ | 4′–7′ | 5′20″ | 13′ |
| B | 5:2 | 7.7 | 1′ | 4′–5′ | 5′ | 16′ |
| C | 5:2 | 47.7 | 1′ | 5′ | 5′ | 8′ |
| C | 5:2 | 38.5 | 1′ | 5′ | 5′ | 9′ |
| C | 5:2 | 21 | 1′ | 11′–12′ | 11′ | 18′ |
| C | 5:2 | 7 | 1′ | 23′ | 21′ | 31′ |
| D | 5:2 | 47 | 1′ | 4′ | 4′ | 7′ |
| D | 5:2 | 39 | 1′ | 3′ | 4′ | 8′ |
| D | 5:2 | 21 | 1′ | 5′ | 4′ | 9′ |
| D | 5:2 (Gm./cm.$^3$) | 6.7 | 1′ | 9′ | 6′ | 13′ |
| E | 2:3 | 47 | 1′ | 4′ | 5′ | 9′ |
| E | 2:3 | 36.5 | 1′ | 5′ | 5′ | 10′ |
| E | 2:3 | 22 | 1′ | 5′–6′ | 6′ | 11′40″ |
| E | 2:3 | 11 | 1′ | 10′ | 10′ | 16′ |

Fig. 4 shows the results of four significant tests with material *B*. It indicates that the resistance of this paste to penetration is reduced as the temperature is raised. The setting time at 46° C. for example, occurs faster than at 37° C., but the Vicat needle always penetrated deeper at 46° C. than at 37° C. The explanation probably lies in the existence of a thermoplastic substance in material *B* which softens at a low temperature. In this respect, the plasticizing temperature of this thermoplastic substance must be higher than the temperature of the oral cavity. Therefore, material *B* should be cooled during setting and immediately after the impression is made, as is done with impression compound.

From the same graph, it is also seen that an increase in temperature reduces setting speed.

### INFLUENCE OF ADDITION OF DISTILLED WATER

Because of the great possibility of impression paste being contaminated by humidity, or the slab or spatula, etc., we have endeavored to determine the importance of contamination by water and also the intentional addition of water.

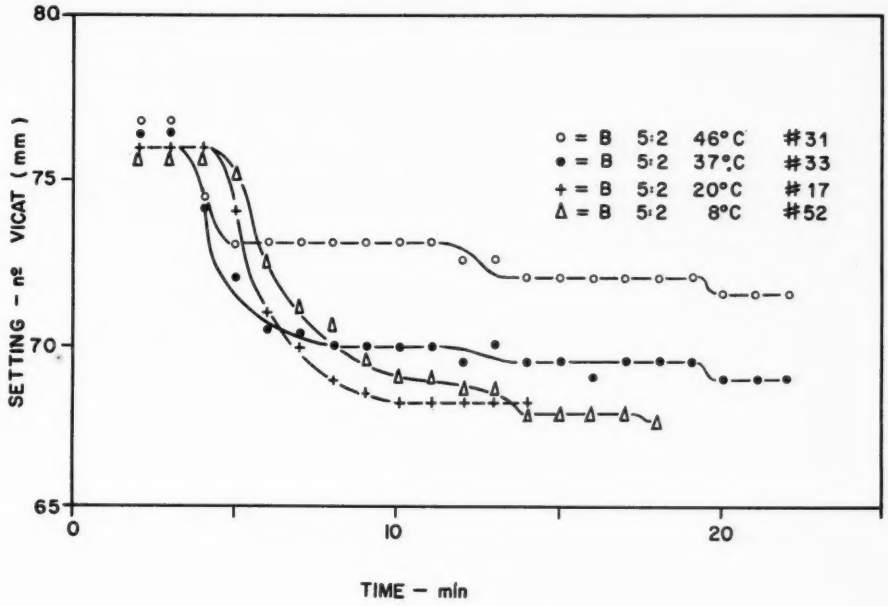


Fig. 4.—The influence of temperature on impression paste *B*.

TABLE V. INFLUENCE OF ADDITION OF DISTILLED WATER

| MATERIAL | ZINC OXIDE/ EUGENOL RATIO (GM./GM.) | TEMPERATURE (°C.) | DISTILLED WATER ADDED (CM.³) | TIME (MIN.) | | | |
|---|---|---|---|---|---|---|---|
| | | | | SPATULATION | LACK OF STICKINESS | SETTING | |
| | | | | | | INITIAL | FINAL |
| A | 3:2 | 20 | 0.10 | 1′ | 32′ | 17′ | 32′ |
| A | 3:2 | 20 | 0.05 | 1′ | 29′ | 17′ | 30′ |
| A | 3:2 | 20 | 0.04 | 1′ | 27′ | 12′ | 28′ |
| A | 3:2 | 20 | —— | 1′ | 21′–24′ | 17′ | 28′ |
| B | 3:2 | 24 | 0.25 | 1′ | 7′ | 9′ | 17′20″ |
| B | 3:2 | 24 | 0.10 | 1′ | 5′40″ | 7′ | 15′20″ |
| B | 3:2 | 24 | 0.05 | 1′ | 6′ | 6′ | 15′ |
| B | 3:2 | 24 | 0.04 | 1′ | 4′40″ | 5′20″ | 11′20″ |
| C | 3:2 | 19 | 0.10 | 1′ | 4′ | 5′ | 10′ |
| C | 3:2 | 19 | 0.05 | 1′ | 4′ | 5′ | 8′ |
| C | 3:2 | 19 | 0.04 | 1′ | 3′ | 4′ | 7′ |
| C | 3:2 | 21 | —— | 1′ | 6′–7′ | 5′30″ | 12′30″ |
| D | 3:2 | 20 | 0.10 | 1′ | 10′ | 8′ | 18′ |
| D | 3:2 | 19 | 0.05 | 1′ | 8′ | 9′ | 17′ |
| D | 3:2 | 19 | 0.04 | 1′ | 10′ | 8′ | 16′ |
| D | 3:2 (Gm./cm.³) | 21 | —— | 1′ | 6′ | 6′ | 14′ |
| E | 2:3 | 19 | 0.10 | 1′ | 10′ | 16′ | 27′ |
| E | 2:3 | 19 | 0.05 | 1′ | 8′ | 8′ | 16′ |
| E | 2:3 | 19 | 0.04 | 1′ | 8′ | 7′ | 13′ |
| E | 2:3 | 22 | —— | 1′ | 5′–6′ | 6′ | 11′40″ |

When water is added in small quantities, the setting time of zinc-phosphate cements can be accelerated. At least one manufacturer whose paste was tested (material *C*) advises that when necessary, a drop of water may be added to the eugenol paste when it is on the slab in order to accelerate the setting time.

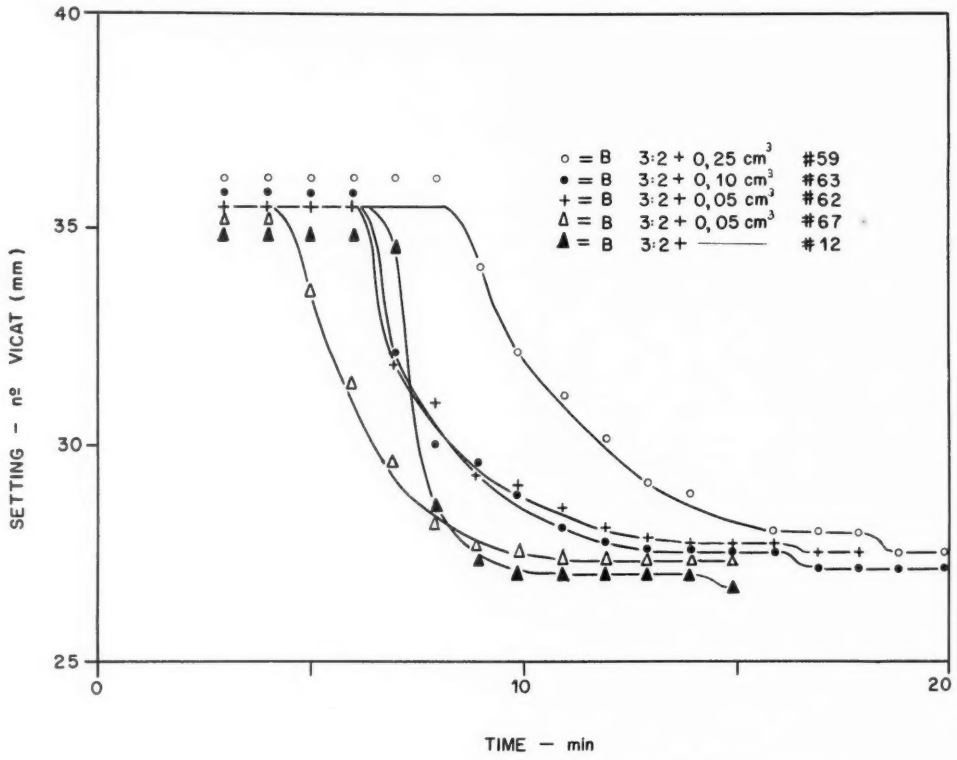


Fig. 5.—The influence of the addition of distilled water to impression paste *B*.

With all experimental variants constant, the following quantities of water were added to the materials before being mixed: 0.25 c.c. (only material *B*), 0.10 c.c., 0.05 c.c., and 0.04 c.c.

Columns 4, 7, and 8 in Table V shows that two materials, *B* and *C*, had their final setting time reduced when 0.04 c.c. of water was added to the mix. However, when 0.05 c.c. of water was added, this reduction did not take place, as the setting time was greater than when water was not added.

Materials *A*, *D*, and *E* behaved differently. The addition of distilled water in the experimental proportions given in Table V always produced a retardation in the initial and final setting time.

What has been said in regard to setting times is also true for the moment at which the pastes lose their stickiness. In these tests, the stickiness ended before the final setting time.

In view of these facts, the addition of water to zinc oxide and eugenol paste is not advisable. It also is not advisable to use instruments affected by humidity, unless, for the determined pastes, the crucial quantity of 0.04 c.c. of distilled water is

added to 5 Gm. of paste which has been prepared under the experimental conditions described and in a 3 : 2 zinc oxide/eugenol ratio.

Fig. 5 shows the setting curves of the four tests made with material *B* to which the different quantities of water were added. The setting time is greater when water is added to the material.

## SUMMARY AND CONCLUSIONS

Some of the factors which affect the setting time of five zinc oxide-eugenol impression pastes have been studied. The earliest time measured from the beginning of spatulation that a Vicat needle failed to penetrate to the bottom of a cylindrical specimen (diameter, 1.7 cm. and height, 0.8 cm.) was called the *initial setting time.* The *final setting time* was measured from the beginning of spatulation until no penetration of the needle occurred.

On the basis of the results obtained, the following general conclusions are presented:

1. In general, the greater the amount of the zinc oxide paste (or powder) employed in proportion to the eugenol paste (or liquid), the less were the initial and final setting times. However, in the case of one paste, the reverse effect was observed. It was assumed that in this case the manufacturer had added the chemical accelerator to the eugenol paste instead of to the zinc oxide paste as in the case of the other four materials.

2. The mixed pastes lost their tackiness in every case before the occurrence of the final set. Consequently, the disappearance of the tackiness (or stickiness) should not be used as an indication that the pastes have set.

3. Both the rate and time of setting are affected by the length of the spatulation time. Within practical limits, the longer the mixing time, the shorter the setting time.

4. The higher the temperature of the mixing pad, the shorter is the setting time.

5. When water in minute amount was added to the eugenol paste (or liquid) before mixing, the setting times of two of the pastes were accelerated, but the set of the other three pastes was retarded. On the basis of the variable results obtained, it was concluded that the addition of water to zinc oxide/eugenol paste is not advisable.

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UNIVERSITY OF SÃO PAULO, SÃO PAULO, BRAZIL

## *TEMPOROMANDIBULAR JOINT DISTURBANCES*

# THE TREATMENT OF EAR, FACIAL, HEAD, AND OTHER PAINS ASSOCIATED WITH PATHOLOGIC TEMPOROMANDIBULAR JOINTS

HARMON SHOHET, D.M.D.*
*Boston, Mass.*

MANY PATIENTS PRESENT THEMSELVES to the dentist and otolaryngologist for the relief of pain originating in or about the temporomandibular joint or ear and radiating to other parts of the face, neck, or head. These frequently are medical problems which must be resolved by the otolaryngologist or other medical specialists. More often, however, they are dental problems, the causes of which are to be found in the oral cavity.

Thus, there is need of close cooperation between the otolaryngologist and dentist, specialists in their respective and closely related fields. That of the dentist, the masticating apparatus, is composed of the joints, the teeth and their surrounding structures, and the jaws and all their supporting and controlling muscles. All these are so closely related that alteration in the function of any one of these structures may result in a disturbance in one or more of the other parts of the apparatus.

Hence, if the vertical dimension of occlusion is closed, if there is occlusal disharmony, unbalanced occlusion, or displacement of the mandible, the facial muscles reflect these abnormalities with resultant strain, tension, fatigue, and spasm of these muscles. The condyles assume an abnormal position in the fossae; there are displacement, compression, and irritation of the soft tissues surrounding the joint and strain of the fibers of the capsule and the ligaments.[1-3]

According to Sicher,[1] an overclosure of the mandible or a mandibular displacement, especially a posterior one, may be followed by a distal subluxation of the lower compartment of the joint articulation. The condyle then impinges upon and finally passes behind the posterior border of the disc, presses against the existing loose connective tissue, rich in blood vessels and nerves, and causes pain and frequent crackling or clicking noises during the opening and closing of the mouth.

According to Granger,[4] the menisci normally translate on the fossae, and the condyles rotate on the menisci. Where there is malocclusion, the teeth may force the condyles to translate on the menisci. Degenerative changes follow, involving the capsule, disc, condyle, fossa, eminence, and soft tissues covering the articulating bones. The nerve and blood supplies located posterior to the meniscus or in the

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*Former instructor in Crown and Bridge Prosthesis, Harvard University School of Dental Medicine, Boston, Mass.

fossa may be disturbed, and the following painful symptoms, generally referred to as the temporomandibular joint syndrome, develop[3]:

Pain at the joint or referred to the ear, face, neck, throat, or temple; noisy, crackling, jerky joints; muscle spasm; trismus of the masticatory muscles causing difficulty in opening and closing the mouth; pain at the joints when biting into hard foods; limited or excessive movement of the joints; tinnitus; stuffy sensation in the ears; mild catarrhal deafness; dizziness; tenderness of the joint on palpation; headache; facial and neck neuralgia; burning or prickling sensation of the tongue; metallic taste; dryness of the mouth; sensation of fullness in the nasopharynx; subluxation; increased or decreased salivation.

It is, therefore, important to establish and maintain correct occlusal architecture and curvature, vertical height, mesiodistal and lateral relationship between the maxillae and mandible, occlusal relationship between upper and lower teeth in all positions of the mandible, and a balanced occlusion. The functional relationship between the upper and lower teeth must always coordinate with a normal anatomic relationship of the components of the joints if the integrity of the joints, teeth, and surrounding soft tissues is to be maintained and the syndrome prevented. In other words, we must maintain a physiologic coordination between the upper and lower teeth, the teeth and fossae, and a normal anatomic relationship between condyles and fossae, and the condyles and the eminences.

## TREATMENT

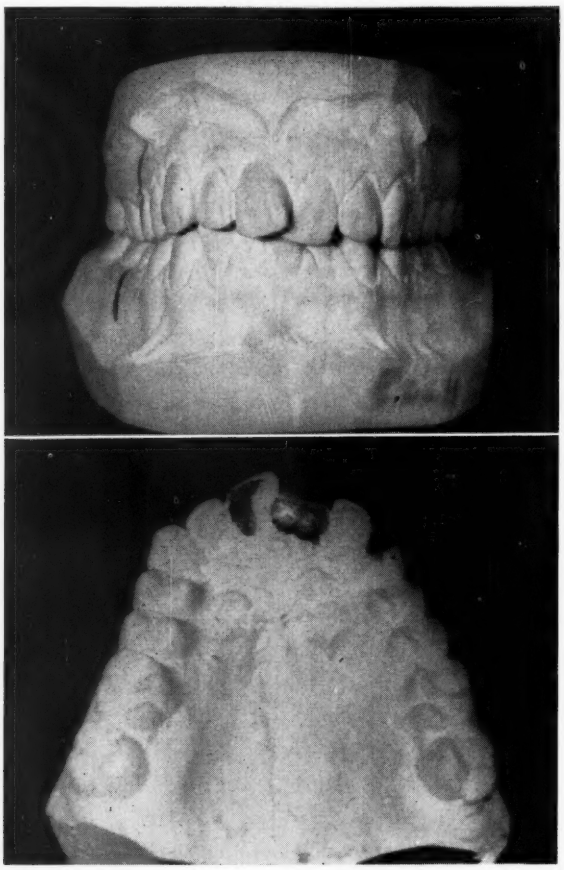
The proper treatment is dependent upon a correct diagnosis and evaluation of: (1) the symptoms and habits, (2) the clinical examination, and (3) the roentgenographic data of the teeth and joints.

It is important to rule out first: (1) pain due to cavities, decay under old fillings, pulp exposures, pulpitis, dying pulps, periapical or periodontal pathology, troublesome or impacted third molars, tic douloureux, rheumatoid arthritis, or other disease and physiologic changes, such as menopause; (2) trauma of the joint due to injury or strain; and (3) habits, such as (a) chewing on one side only or with the anterior teeth, (b) sleeping on the stomach with the weight of the body on the chin, (c) frequent resting of a hand against the mandible while reading, studying, watching TV, or listening to the radio, (d) the prolonged retention in the mouth of large and hard objects, such as a pipe stem, (e) clenching of the teeth and bruxism, resulting in muscle tension and spasm, and (f) leaving dentures (particularly complete dentures) out of the mouth during sleeping hours.

All abnormalities of the occlusion, cuspal interferences, premature contacts, mandibular displacements, too short or too great vertical dimensions of occlusion, deep and irregular occlusal planes, extrusions of individual teeth causing locking of the occlusion, infraocclusion or supraocclusion, and unbalanced occlusions are treated in the following manner:

Premature contacts, cuspal interferences or other occlusal disharmonies responsible for locking or displacing of the mandible, and some extrusions can be relieved by judicious and careful occlusal equilibration, at all times avoiding reduction of the vertical height (Figs. 1 and 2).

Other patients may require more elaborate dental treatment as follows: (1) correcting an unbalanced occlusion by replacing missing posterior or anterior teeth (Fig. 3), or correcting an anterior infraocclusion with a Hawley plate; (2) the use of a temporary occlusal block to quickly correct a malocclusion and a malrelationship between the maxillae and the mandible, to balance the occlusion, to unlock the occlusion, and to restore lost vertical height, thus giving the patient

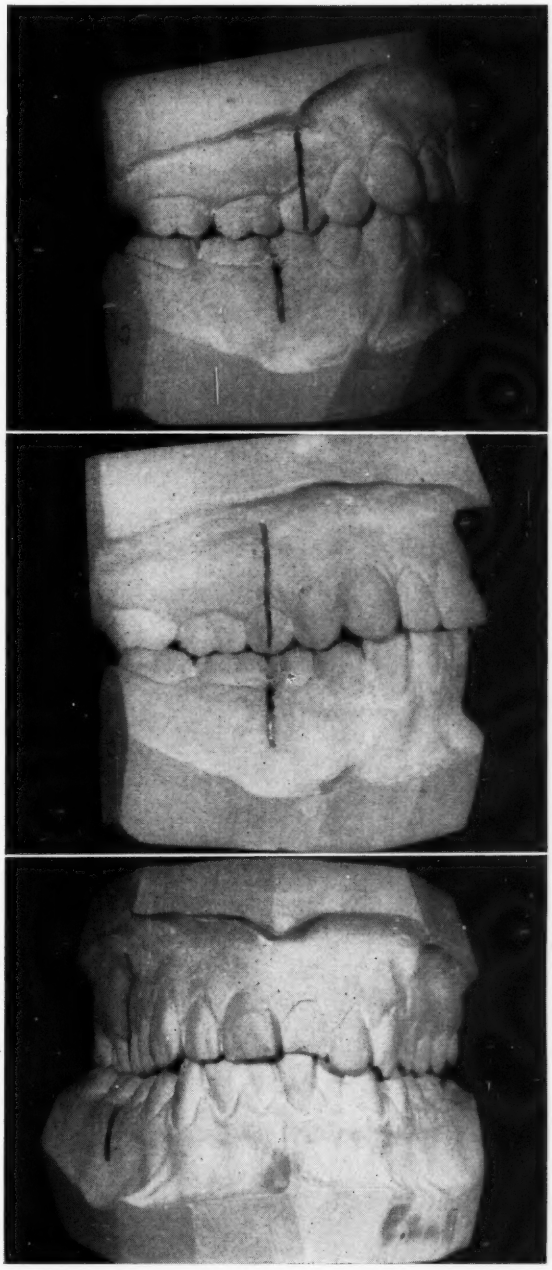


*A.*

*B.*

Fig. 1.—*A*, Before treatment, showing a right-lateral displacement. *B*, The maxillary teeth showing the interferences causing the displacement. These interferences as indicated are to be removed by grinding.

immediate relief from painful symptoms (Fig. 4); (3) the use of the Hawley plate to prevent bruxism, to relieve muscle tension and spasm, to open the bite, and to encourage further vertical development and eruption of the posterior teeth of young patients by keeping the posterior teeth in infraocclusion (Figs. 5, 6, and 7); (4) restoring infraocclusion in the posterior or anterior parts of the mouth with inlays or crowns; and (5) complete mouth rehabilitation (Figs. 3 and 8) in order to restore normal anatomic crown forms and occlusion, vertical height



*A.*

*B.*

*C.*

Fig. 2.—*A,* Before removing upper interferences. Note the distal displacement of the mandible. *B,* After treatment. The mandible automatically repositioned itself to a normal relationship after the interferences, shown in Fig. 1, were eliminated by grinding. *C,* After treatment. Note the normal maxillomandibular relationship. Compare with Fig. 1, *A.*

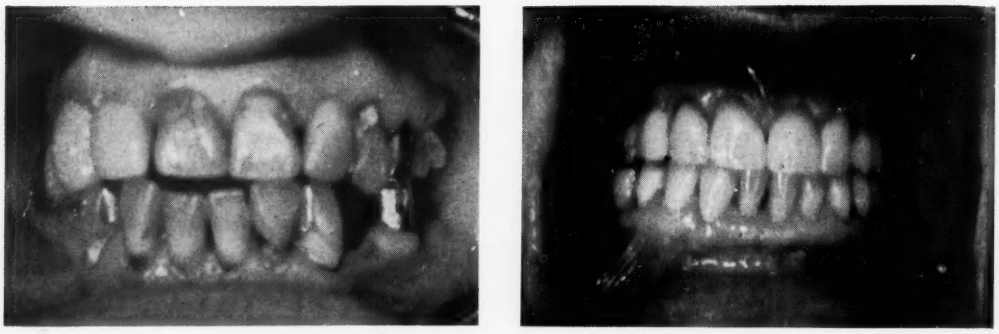


Fig. 3.—Occlusal disharmony and an unbalanced occlusion are corrected by permanent, complete rehabilitation. Left, Before treatment. Right, After treatment.

*A.*

*B.*

*C.*

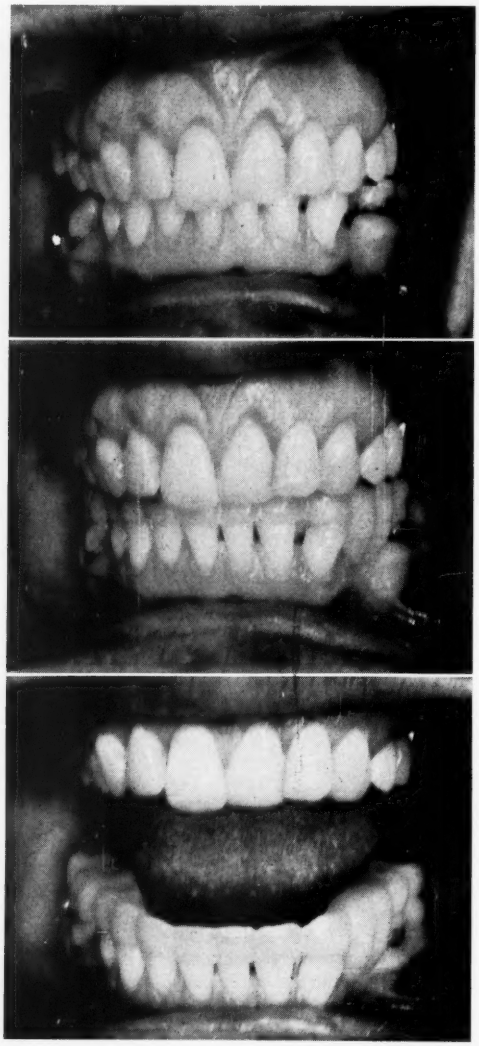


Fig. 4.—Vertical dimension closure is restored temporarily with an occlusal block for the relief of symptoms. *A*, Before insertion of the occlusal block. *B*, The occlusal block placed in position showing the restored vertical dimension. *C*, The occlusal block is in place with the mouth open.

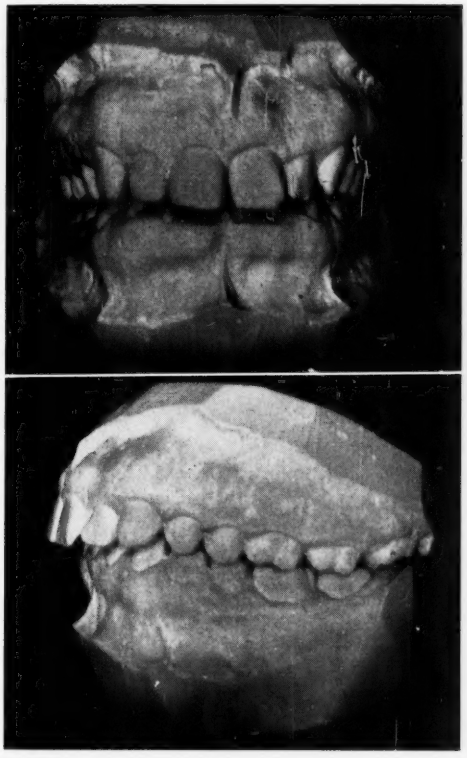


Fig. 5.

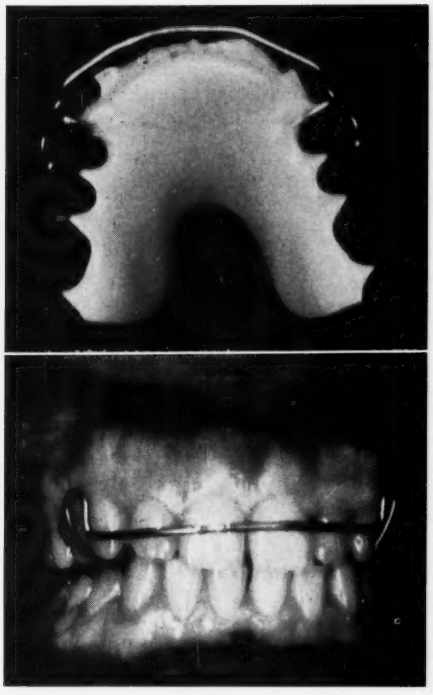


Fig. 6.

Fig. 5.—A patient 18 years of age with an extremely shortened vertical dimension. The symptoms were relieved by opening the vertical dimension with a Hawley plate. The patient was permitted to wear this plate for a long period of time to permit the gradual vertical eruption of the posterior teeth.

Fig. 6.—*A*, The acrylic resin Hawley plate which kept the posterior teeth in infraocclusion. As the posterior teeth extruded and moved into contact, the vertical dimension was again opened slightly by adding acrylic resin to the anterior segment of the plate. *B*, The Hawley plate in position.

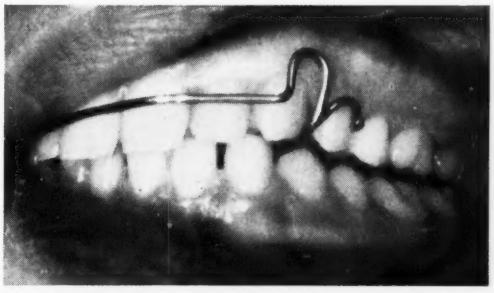


Fig. 7.—A Hawley plate is in position, showing the posterior teeth in infraocclusion.

lost through erosion, attrition, extraction, or malocclusion (Figs. 7 and 8), to balance the occlusion, and to effect a functional relationship between the upper and lower teeth.[4,6,8]

Finally, the following supportive treatments may be helpful: (1) application of dry heat to the joints, (2) resting the joint by avoiding hard foods, excessive chewing, and wide opening, (3) resting the joint and muscles by immobilization with an ACE bandage, (4) the use of sedatives and other medication, and (5) the injection of hydrocortisone into the joint to relieve painful trismus or a fibrosing agent correct excessive loose movement of the joint.

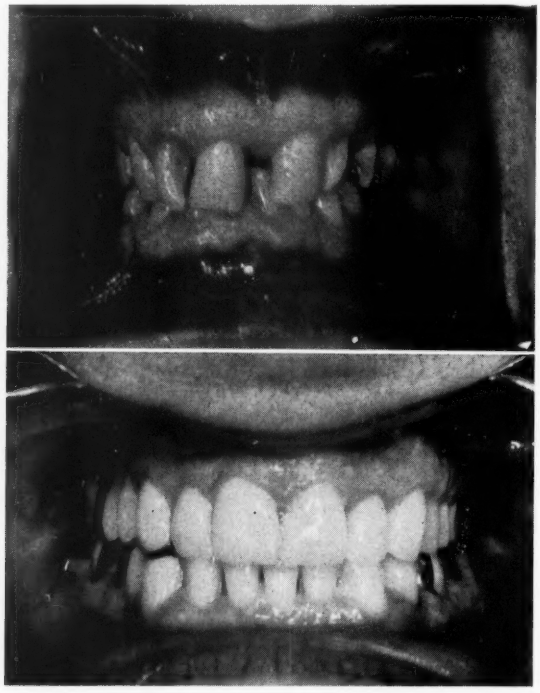


Fig. 8.—Excessive vertical dimension closure is restored permanently by complete mouth rehabilitation.

OCCLUSAL EQUILIBRATION

After ruling out all dental factors previously referred to (under Treatment) and having prescribed the necessary supportive treatments and ways and means of eliminating objectionable habits, the first concern of the dentist is the correction of the occlusion to eliminate high spots and cuspal interferences.

The correction of every premature contact is important. In fact, a single high spot or one cuspal interference is enough to displace the mandible and cause discomfort and other symptoms (Figs. 1 and 2).

Various methods of procedure have been prescribed, but the following suggestions may be helpful:

1. Articulated casts are carefully studied, and all obvious extrusions and interferences are indicated. These markings are then transferred to the patient's teeth,

and the recorded areas are reduced by careful grinding. (Figs. 1 and 2 show a step-by-step procedure in the treatment of a distal and lateral displacement responsible for many disturbing symptoms. These were relieved by occlusal grinding only.)

2. The occlusion is checked in centric position. The patient is relaxed with sedatives, if necessary, and placed in a comfortable upright or supine position. Using a central bearing apparatus, where necessary, and articulating paper shaped to cover the entire occlusion, the patient is requested to "tap, tap" quickly, but very lightly, while the dentist applies gentle finger pressure to the patient's chin. (Strict adherence to details in this procedure is important; otherwise, the patient may start to occlude in centric relation, but with a labored closure he will direct the mandible into a forced or habitual eccentric relation by cuspal interferences or mere habit.) The interferences and high spots of all inclined planes indicated by the articulating paper are carefully ground away. It is generally better not to reduce the tip of a cusp if it is in premature contact in centric occlusion only. The opposing fossa is reduced instead.

3. Anterior prematurities can often be detected with the tips of the dentist's fingers placed over the upper teeth while the patient is asked to "tap, tap" the teeth together.

4. In the lateral excursions, the grinding is limited to the inner inclines of the maxillary buccal cusps and the mandibular lingual cusps.

5. The upper anterior teeth are ground from the centric occlusal mark to the incisal tip and laterally to the marginal ridges.

6. Most of the grinding of the posteriors is limited to the inclined planes from the centric occlusal mark downward.

7. The tip of a cusp is ground only if it is premature in centric occlusion and in all excursive movements (balancing and working positions), or if it causes a locking of the occlusion or a displacement of the mandible. Otherwise, the grinding is limited to the opposing fossa and the cuspal inclines. Tests are made for all three positions before a cusp is ground.

8. It is important to reduce the prematurities on the balancing side as well as the working side, but a cusp that may be necessary to maintain centric occlusion must not be reduced. Its opponent is reduced instead.

9. The reduction of the vertical height is avoided by every means possible.

10. Grind only where it is indispensable to eliminate a premature contact, to unlock the bite, reposition the mandible, and allow freedom of movement of the mandible (Figs. 1 and 2).

11. Be sure the true centric occlusion is retained after all the grinding is done.

12. Reshape and polish the teeth after grinding.

13. If a tooth cannot be taken out of a pathologic occlusion by grinding, or if a tooth, responsible for a locking or displacement of the mandible, cannot be corrected by grinding, it must be cut down and rebuilt with an artificial crown or extracted.

14. Teeth in infraocclusion must be built up to a normal centric occlusion. All restorations must be tested and adjusted to all excursive positions.

15. Whether the occlusion is reduced or restored, all modifications should

be made as far as possible in a manner that will (a) direct the stress through the long axis of the teeth, (b) reduce the stress to the minimum with correct occlusal anatomy and even distribution of load, and (c) retain the normal free-way space.

OCCLUSAL BLOCKS

Occlusal blocks are used (1) to give the patient immediate relief from discomfort, (2) to re-establish a normal relation between the components of the temporomandibular joint by restoring the normal vertical height and repositioning the mandible, (3) to test out a new vertical height before proceeding with complicated, permanent restorations, and (4) to act as a guide in the permanent reconstruction.

These occlusal blocks can be made of acrylic resin or metal (Figs. 4, 9 and 10). (Figs. 11 to 14 show a step-by-step procedure in the construction of a maxillary and mandibular acrylic resin occlusal block to restore the lost vertical occlusal dimension, to balance the occlusion, and thus relieve the patient of all symptoms.) The acrylic resin type is preferred because of simplicity of construction and because it can be easily altered, i.e., the vertical height can be increased or decreased. The metal type of occlusal block is used where the vertical dimension of occlusion is to be increased only slightly and where the rigidity and strength of metal is necessary. It is generally sufficient to build an occlusal block for one arch only. However, both upper and lower occlusal blocks are necessary for some patients (Fig. 12).

Accurate casts of both arches are articulated in the correct centric relation for the predetermined, new vertical height. Clasps may be used for retention, but they are not generally required. The usual procedure is to carry the lingual or palatal sections of the appliance over the teeth as occlusal extensions and replace any missing teeth (Figs. 4 and 10). It is important to construct the occlusal surfaces of these occlusal blocks flat without cusps or deep carvings. The idea is to prevent any interdigitation with the opposing occlusal surfaces in order to allow the mandible complete freedom of movement so that it can find its own true centric position. The occlusion must be adjusted to all excursions of the mandible.

Whenever possible, it is desirable to include the anterior as well as the posterior teeth in the occlusal block. By thus distributing the load and balancing the occlusion, the posterior teeth will not be depressed into their sockets, particularly if the vertical dimension of occlusion has been merely restored to normal.

These occlusal blocks are worn all of the time, if possible. If necessary, they may be removed during meals. When worn for therapeutic reasons, they are discarded during the day after the symptoms have disappeared and are then worn during the sleeping hours only. Patients are required to wear occlusal blocks for weeks or months, or until all of the symptoms have disappeared. Should the symptoms reappear, as they sometimes do, the occlusal block is worn again.

These appliances are not intended for permanent use. The mouth should eventually be rehabilitated with the necessary restorations.[6] Meanwhile, it is important that the appliances and the supporting teeth be kept clean to prevent decay. Also, the patient must be seen periodically so that the occlusion may be checked and the teeth examined for decay and vertical movement.

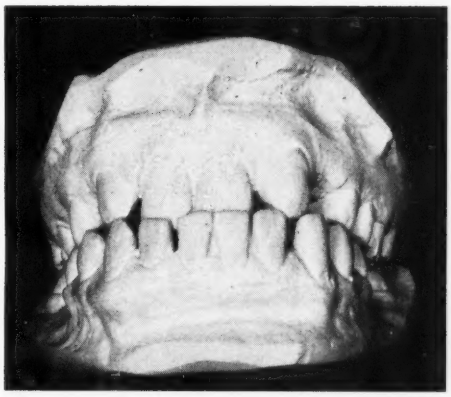
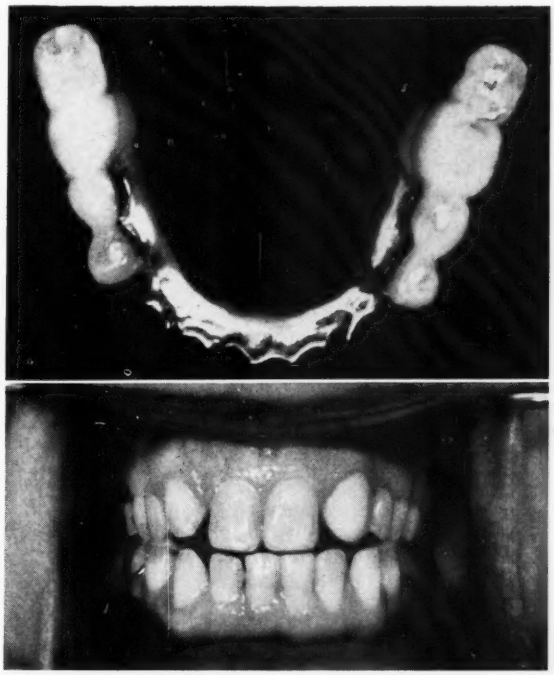


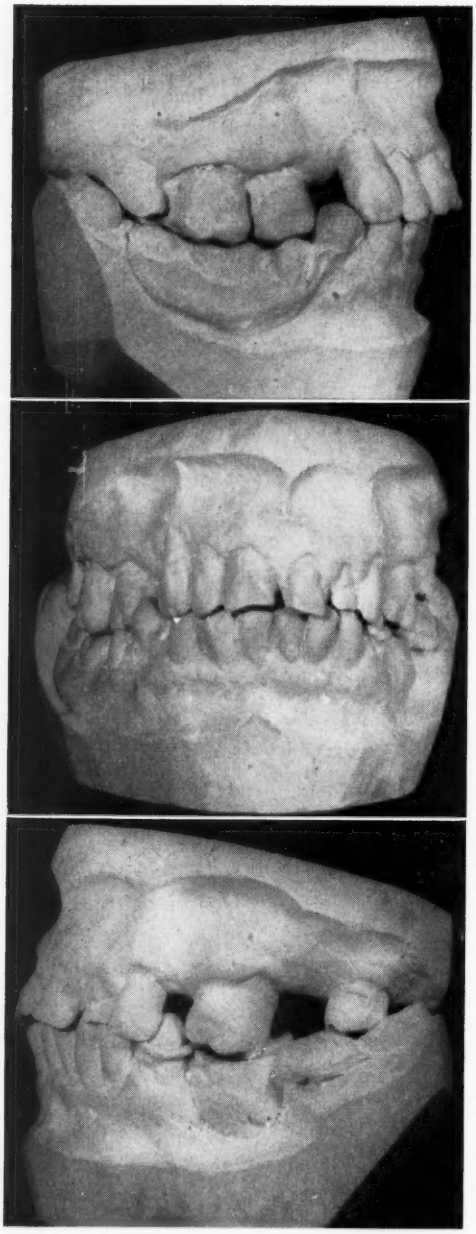
Fig. 9.—A mesial mandibular displacement which is responsible for many disturbing symptoms.

*A.*



*B.*

Fig. 10.—*A*, The occlusal block which relieved the symptoms by increasing the vertical dimension of occlusion and eliminating the "locking" of the mandible. *B*, The occlusal block is in position.

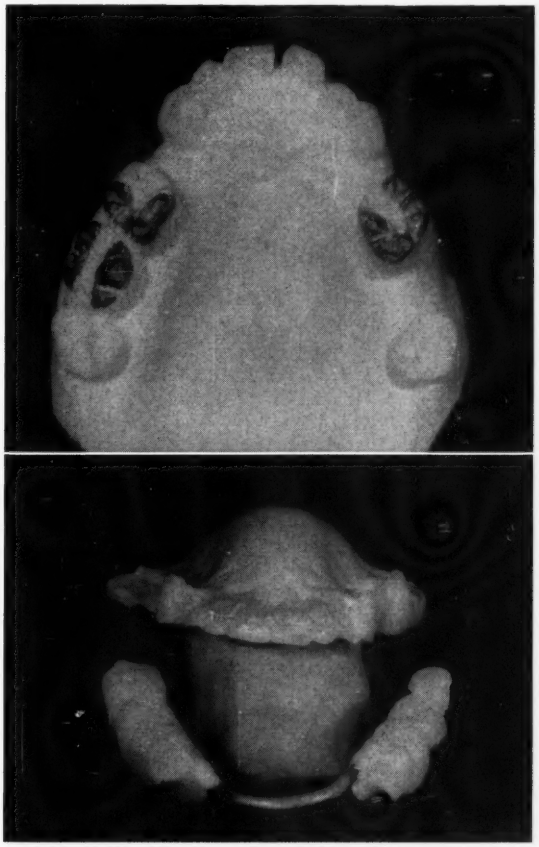


*A.*

*B.*

*C.*

Fig. 11.—*A*, Marked closure of the vertical dimension and locking of the occlusion. Note the old denture worn by the patient. Note also the irregular lower occlusal plane. *B*, Before treatment. *C*, The old denture is in place.



*A.*

*B.*

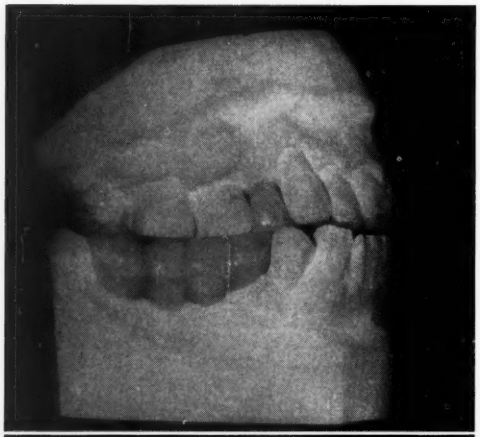
Fig. 12.—*A*, The maxillary stone cast indicating three extruded molars which must be relieved to bring them into a more normal occlusal plane. *B*, The maxillary and mandibular waxed-up occlusal blocks.

## HAWLEY PLATES

For younger patients where there is possibility of vertical depression of the posterior teeth from the conventional type of occlusal block, the Hawley type plate is preferred (Figs. 5, 6, and 7). This plate is constructed so that only the anterior teeth are in occlusion, leaving the posterior teeth in infraocclusion (Fig. 7). Thus increased, the vertical dimension of occlusion will function as with the conventional occlusal block, giving immediate relief of pain in acute cases and, at the same time, allowing the posterior teeth to erupt to the new height established by the anterior tooth contact. By periodically adding to the anterior acrylic resin seat, the vertical dimension of occlusion is increased gradually, and further eruption of the posterior teeth is permitted.

After the posterior teeth have erupted to the desired vertical height, the appliance is worn during sleeping hours only. This is in order to correct any de-

A.



B.

Fig. 13.—*A*, The waxed-up occlusal blocks are placed on the casts, and the vertical dimension is restored to normal. Note the improved occlusal planes, the unlocking of the occlusion, and the restored vertical dimension as compared with Fig. 11, *A*. *B*, The waxed-up occlusal blocks on the casts.

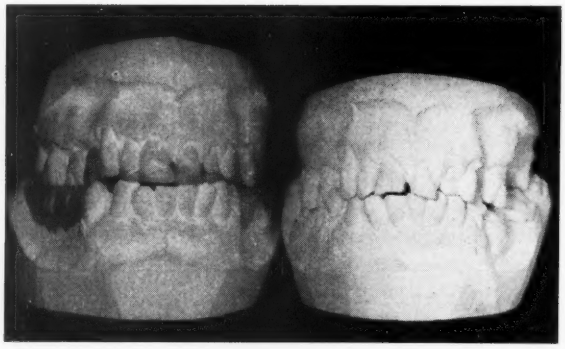


Fig. 14.—*A*, The maxillary and mandibular casts with the two occlusal blocks in position. *B*, The occluded casts before treatment.

pression of the posterior teeth developed during the time the appliance is kept out of the mouth. This procedure may be necessary for many months. Excellent and permanent correction in vertical height can often be obtained, especially with young patients.

If, after several months' use of the Hawley plate, there are no indications of vertical extrusion of the posterior teeth, the occlusion of these teeth must be built up by prosthetic measures.[6] However, with young patients, orthodontic treatment may be resorted to first.

The Hawley plate is also useful therapeutically for patients with a maxillary protrusion where the upper anterior teeth are in infraocclusion. Because of the absence of contact between the upper and lower anterior teeth, the patient is constantly reaching out with the mandible and straining the joint. The Hawley plate will prevent and relieve this strain by providing anterior contact.

## DETERMINATION OF THE NORMAL OCCLUSAL VERTICAL DIMENSION AND REGISTRATION OF CENTRIC RELATIONSHIP

In every type of restoration, the occlusal vertical dimension should not be stretched but merely restored to a vertical height normal for the age of the patient. This is best determined by measuring the physiologic rest position (distance) and subtracting from it about 3 mm., the average normal free-way space (interocclusal distance). However, any vertical height selected must be consistent with good cosmetics in both the frontal and the lateral views, and must be confirmed by testing the new occlusal height with a temporary occlusal block worn several days or weeks.

The physiologic rest position is that position of the mandible at which the lips barely touch and the muscles of the face are completely relaxed. It is a neutral and resting position of the mandible with a complete balance of all the muscles suspending the mandible.[6]

The following are methods of registering the rest position. Each method should be tried and confirmed with the other three.

*Method 1.*—A small strip of adhesive tape with a dot inscribed on it is placed on the tip of the patient's nose. Another piece, similarly inscribed, is placed on the chin.[3] It is necessary to obtain complete relaxation and balance of all the muscles suspending the mandible. Therefore, it is suggested that the patient be placed in a comfortable and completely relaxed position. Sometimes it is helpful to premedicate the patient with a sedative or tranquilizer. The position of choice is an erect sitting or a standing position. The patient is requested to relax, open the mouth wide, and then bring the two jaws together slowly until the lips barely touch. This is the physiologic rest position. The patient must be warned not to bring the teeth together, but to rest the jaws after the lips make contact. The distance between the two points is measured with a pair of calipers. This should be confirmed with a second measurement, and the calipers are then locked.

*Method 2.*—The preliminary procedures are the same as described in Method 1. After the patient is relaxed, he is asked to swallow and rest without bringing

the teeth together. The measurement between the two dots is taken. A second trial is used for confirmation.

*Method 3.*—With the same preliminary procedures, the patient is requested to repeat slowly two or three times the name "Emma" and then rest without bringing the teeth together. The measurement is taken during the moment of rest.

*Method 4.*—The same preliminary measures are used. The patient is then asked to take a deep breath through the mouth and out through the nose. This method is particularly helpful with high-strung patients. The deep breathing helps them relax. The measurement is taken during the moment of complete rest after several inhalations and exhalations.

With the mandible now brought into the occlusal position, one pointer of the previously measured and locked calipers is superimposed on the dot on the nose, and another dot is inscribed where the lower pointer meets the adhesive on the chin. The distance in millimeters between the two dots on the chin represents the difference between the physiologic rest and occlusal positions, or the interocclusal distance, and indicates if the vertical height is normal or if it requires modification, considering 3 mm. as the normal average distance.

## THE OCCLUSAL LEVEL

A simple procedure for determining the correct occlusal level in any new construction, or any reconstruction requiring alteration of the existing vertical height, is as follows:

Having determined and measured the physiologic rest position, a hard wax occlusion rim is built up to the correct vertical height, utilizing the caliper registration and the markings on the adhesive, in accordance with the formula: the vertical occlusal height equals the physiologic rest position minus the interocclusal distance. This occlusion rim, fabricated so that the occlusal wax makes even contact with all of the opposing teeth, is first built up to the physiologic rest position height, and then it is reduced 3 mm. to bring it down to the normal vertical occlusal height.[6]

Shanahan[5] determines the vertical height by placing one small, soft wax cone on the right and another on the left first molar regions of a reduced lower occlusion rim and requesting the patient to swallow. As the patient does so, he will depress the tops of the soft wax cones. This represents the normal vertical occlusal height.

## CENTRIC RELATION

To register centric relation, the patient is not permitted to "bite" into the completed wax occlusion rim regardless of how soft it may be. To do so might bring about a dislocation of the condyles in the fossae, and, thus, the entire subsequent registration and the reconstruction made with it would be inaccurate. Therefore, after the occlusion rim is constructed to the correct occlusal level, a thin mix of zinc oxide and eugenol impression paste is spread over it, and the mandible is guided by the operator into the correct centric position with gentle finger pressure applied to the chin while the patient swallows. This position is maintained until the material has hardened.[3]

### PRECAUTIONS TO BE OBSERVED WHEN MAKING ROENTGENOGRAMS OF THE TEMPOROMANDIBULAR JOINT

Similar precautions are necessary when roentgenograms of the temporomandibular joint are made in the open-mouth position. The usual procedure is to request the patient to "bite" into a rubber prop. This is accompanied with more or less pressure by the patient. This pressure may cause a dislocation of the condyle in the fossa, and, thus, the subsequent roentgenogram will indicate an induced relationship that is actually nonexistent and, therefore, may be the cause of an incorrect diagnosis. Hence, it is important to caution the patient to avoid biting into the prop with any pressure and to use the prop merely as a means of resting the mandible at the desired opening.

### MOUTH REHABILITATION

Most patients with temporomandibular disturbances can be treated and helped by one or more of the methods already described, with the majority responding to either occlusal adjustment or the use of the occlusal block (Fig. 10). However, many patients finally require permanent reconstruction (Figs. 3 and 8). Various methods have been described.[6] The method of choice varies for each dentist and for each patient.

New and more complex adjustable articulators have been developed recently.[7,8] Some of these are recommended where rehabilitation is indicated. It must be noted, however, that all articulators are masses of cold, inflexible, hard metal lacking the all-important neuromuscular factor. They cannot be made to respond to all of the complex and varied direct and indirect stimuli to which the living mechanism is constantly being subjected. Perhaps Schweitzer[7] states it more succinctly, "Most of us still insist that it is impossible to copy jaw function on any machine."

These newer types of instruments are not indispensable, and good results have been obtained consistently by many dentists with simpler apparatus. Nevertheless, these new appliances permit a physiologic coordination between the upper and lower teeth and the teeth and the fossae to a degree greater than was formerly considered possible.[8] Like all other articulators, these are merely tools. Their successful use depends upon the skill of the dentist and the care with which they are employed. They must not be condemned because of serious errors resulting from careless use. It is well to remember the quotation from Julius Caesar, "The fault, dear Brutus, is in ourselves."

### A SYSTEM FOR OFFICE PROCEDURE

I. Record the age of the patient and the history relating to the present problem, noting especially any accidents causing trauma of the joints or surgery involving the mouth, face, neck, joints, or ears. Determine if the patient is in menopause.

II. Record the chief complaint.

III. Record other symptoms.

IV. Make temporomandibular roentgenograms in the open- and closed-mouth positions.

V. Make roentgenograms of the teeth.
VI. Make impressions for study casts.
VII. Make a careful clinical examination.

1. Extraoral: (a) Note the pattern of movement of the condyles, and check this with the little finger inserted in the meatus of the outer ear. (b) Note muscle spasms, clenching or grinding of the teeth, expression of the face, lips, tone of face tissue, wrinkling, or stretching of tissues. (c) View the frontal and lateral sides of the face for evidence of reduced or excessive vertical dimension of occlusion. (d) Note the pattern of movement of the chin. (e) Palpate the joints for sensitivity or tenderness in the closed position and during jaw movement. (f) Note the degree of the mandibular movement. (g) Measure the interocclusal distance to determine the vertical height of occlusion and rest position.

2. Intraoral: (a) Examine the gingivae for evidence of periodontal disease, and other pathosis. (b) Examine the teeth for cavities, pulp exposures, loose or leaky fillings, dying pulps, pulpitis, third molar involvement, and other pathosis. (c) Note any tooth extrusions and record them on the study casts. (d) Note and record on the study casts locked occlusions indicating the particular teeth involved (Figs. 11 and 12). Determine whether the patient can move the mandible freely in all directions. (e) Note and record on the study casts any premature tooth contacts or occlusal disharmonies on the balancing as well as on the working sides. (f) Note and record all other cuspal interferences. (g) Note any displacement of the mandible, and differentiate between the normal centric position and the habitual or forced eccentric position, and indicate the causes and the nature of the displacement: distal, mesial, or lateral. (h) Check the vertical height to determine if it is too great or too short to distinguish between a vertical overlap and a decreased vertical dimension, and between a horizontal overlap and a displacement. (i) Note and record unbalanced occlusions. (j) Note infraocclusions.

VIII. Habits.

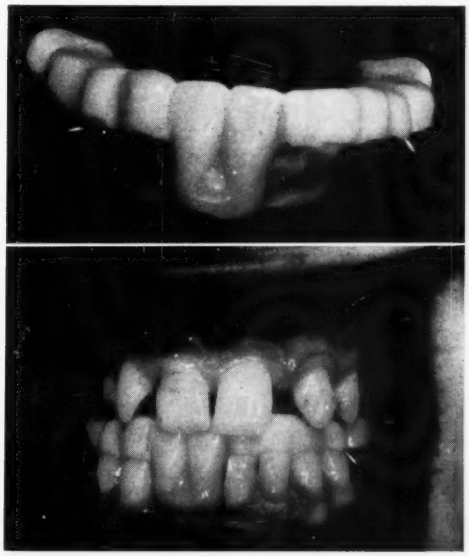
(a) Eating—determine if the patient chews mostly on one side or with the anterior teeth and why. (b) Smoking—determine if the patient keeps a pipe stem or any other large, hard object between the teeth a good part of the day. (c) Sleeping—determine if the patient sleeps on the stomach with the weight of the body on the chin. (d) Note possible grinding habits (bruxism), and determine if they occur during the day or sleep. (e) Note clenching habits, and watch for facial muscle tension and spasms. (f) Record the patient's reading, viewing TV, and radio habits. (g) Determine if the patient keeps his removable partial or complete dentures out of the mouth during sleeping hours.

IX. Prescription for treatment.

(a) Prescribe the application of heat to relieve trauma caused by injury or strain. (b) Advise rest and the avoidance of wide opening or biting into hard foods. (c) Immobilize the mandible with an ACE bandage in acute cases. (d) Medicate with sedatives to relieve pain, and tranquilizers to relax the patient and relieve muscle spasm. (e) Treat the joints by injections of hydrocortisone or sodium psyliate (fibrosing agent). (f) Eliminate disturbing habits. (g) Instruct the patient to keep all removable dentures in the mouth during the sleeping hours.

(h) Do all of the necessary general dentistry: periodontal treatment, fillings, pulp cappings, extractions; check and correct all old or deep fillings to rule out the possibility of pulp exposures, pulpitis, or dying pulps; check all old inlays and crowns by removing them, if necessary; and eliminate all pathosis and third molar involvements. (i) Rule out tic douloureux, rheumatoid arthritis, or other disease and physiologic changes like the menopause. (j) Equilibrate the occlusion, removing all premature tooth contacts and all causes for locking of the occlusion or displacing the mandible. (k) Balance the occlusion with the necessary replacements, temporarily for immediate relief of symptoms. (1) Increase the vertical dimension of occlusion, as required, with a temporary occlusal block for the immediate

Fig. 15.—A decreased vertical dimension caused many painful symptoms which were relieved by an occlusal block.



*A.*

*B.*

Fig. 16.—*A*, The acrylic resin occlusal block restored the normal vertical occlusal height. *B*, The occlusal block which gave immediate relief is in position.

relief of symptoms (Figs. 4, 15, and 16). (m) Correct anterior infraocclusion with a Hawley plate. (n) Correct infraocclusion in the posterior or anterior parts of the mouth with inlays or crowns. (o) Accomplish a complete mouth rehabilitation where it is indicated (Figs. 3 and 8).

## CONCLUSIONS

1. Many facial pains and pain originating in or about the ear are related to the temporomandibular joint mechanism.

2. Eliminating the factor of strain, disease, or injury, the temporomandibular joint syndrome may be due to: (a) occlusal disharmonies or premature occlusal contacts, (b) a decreased vertical dimension of occlusion or an unbalanced occlusion, (c) a locked or displaced mandible, or (d) a malrelationship between the maxillae and the mandible and between the components of the joint mechanism.

3. Several methods of treatment are described. Excluding those cases due to trauma and the true arthritic types of temporomandibular joint disturbances, most patients will be relieved of their symptoms by (a) occlusal adjustment and occlusal equilibration, (b) restoring the normal vertical dimension, (c) restoring the normal anteroposterior and lateral relationships, and (d) eliminating disturbing habits.

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20 Gloucester St.
Boston, Mass.

# TREATMENT OF TEMPOROMANDIBULAR JOINT DISTURBANCES CAUSED BY CHRONIC PARTIAL SUBLUXATION

ORLAND J. CASELLI, D.D.S.
*Sacramento, Calif.*

THE ETIOLOGY AND TREATMENT of temporomandibular joint disturbances are varied. The type of treatment described in this article applies to those patients with temporomandibular joint disturbances caused by chronic subluxation of the condyles.

## SYMPTOMATOLOGY

Patients with temporomandibular joint disturbances have almost identical symptoms and complaints. Some of these are: (1) deflective occlusal contacts in centric and eccentric positions of the mandible, (2) clicking and cracking during opening of the mandible, (3) limited opening of the mandible, (4) swelling over the temporomandibular joint area with referred pains, (5) itching and/or feeling of pressure within the auditory canal, (6) deviation of the mandible away from the subluxated side in unilateral subluxation, (7) symptoms closely related to tic douloureux, (8) a burning sensation of the throat, tongue, and side of the nose, (9) dry mouth with almost no saliva, and (10) headaches.

## CAUSES

Traumatic influences, either intrinsic or extrinsic, or a combination of both, are causative factors in temporomandibular joint disturbances. Some of these are: (1) yawning to a point of subluxation, (2) blows to the back or side of the head that catapult the mandible forward out of the glenoid fossa, (3) falls, (4) traumatic causes that may produce pressure to move either or both condyles out of, or partially out of, the glenoid fossae, (5) frequent and prolonged neck traction by means of head halters, (6) cuspal or occlusal disharmony, (7) vehicular accidents that cause the patient to receive the so-called "whip-lash" injury to the head and neck, (8) muscle trismus, such as that following the removal of infected third molars and osteomyelitis, (9) shock therapy for mentally ill patients, (10) lack of molar teeth, and (11) loss of all teeth which permits overclosure, tenderness to palpation, looseness of the condyles within the joint capsule, and weaving of the condyles from side to side upon opening and closing of the mandible.

## FINDINGS

Most of the literature on temporomandibular joint disturbances described the injury, pain, edema, limited motion, and deviation to be on the side that is par-

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tially subluxated. However, the pathology is contralateral. The side opposite that condyle which is displaced partially out of the glenoid fossa exhibits pain and the related disturbances. These pains result from the pressure of the condyle against the anterior wall of the auditory canal and the chorda tympanic nerve. The side that shows the greater space between the distal and upper surface of the condyle and the wall of the articular disk is the subluxated side. It will generally "pop" and "grate," but it is not particularly painful.

### MUSCULATURE

The masseter, temporal, internal pterygoid, and external pterygoid muscles, together with the combined accessory musculature of the mandible, move the mandible into the path provided by the partially subluxated position in which the condyles are held by the capsule. The damage to the temporomandibular joint is effected while the mandible is being closed and not during opening. When the mandible is opened, the action of the external pterygoid and inframandibular muscles moves the condyle on the partially subluxated side out of the glenoid fossa, and this, in turn, forces the opposite condyle backward against the capsule causing adverse symptoms.

### ETIOLOGY

The space between the distal and superior surfaces of the condyle and the articular capsule is about 3 to 4 mm. in a partially subluxated condyle. This measurement varies, but will be in direct ratio with the amount of anterior displacement of the mandibular teeth on the subluxated side.

The displacement of the median line away from the subluxated side will also be in a direct ratio to the anterior displacement of the mandibular teeth on the subluxated side. This condition is caused by the intrinsic or extrinsic forces already described. The musculature of a patient will compensate to different vertical dimensions of occlusion which may develop at varying ages and also to cuspal interferences. The perfectly balanced dentition is seldom seen in the average patient. However, even when the occlusion is not balanced, and in spite of cuspal interference, a natural harmony is found between the musculature and the temporomandibular joint with none of the pain and disturbances that are found in partial subluxation. Therefore, it is necessary for the temporomandibular joint to be partially subluxated before pain disturbances are exhibited.

### ROENTGENOGRAM FINDINGS

The disturbed partially subluxated temporomandibular joint may be seen roentgenographically to exhibit almost twice the amount of space between the distal and superior surface of the condyles and the articular capsule than is seen on the opposite side (Fig. 1). On the opposite side, there is very little or no space between the distal and superior surface of the condyle and the glenoid fossa (Fig. 2). This lack of space causes pressure on the Eustachian tube and the chorda tympanic nerve.

TREATMENT BY USE OF TRACTION

It is of the utmost importance to recognize that the greater pain and related symptoms will be present in the joint in which the condyle has been forced posteriorly. Therefore, it is necessary to reposition both condyles into their normal positions. The chronically subluxated condyle is held partially out of the glenoid

Fig. 1.

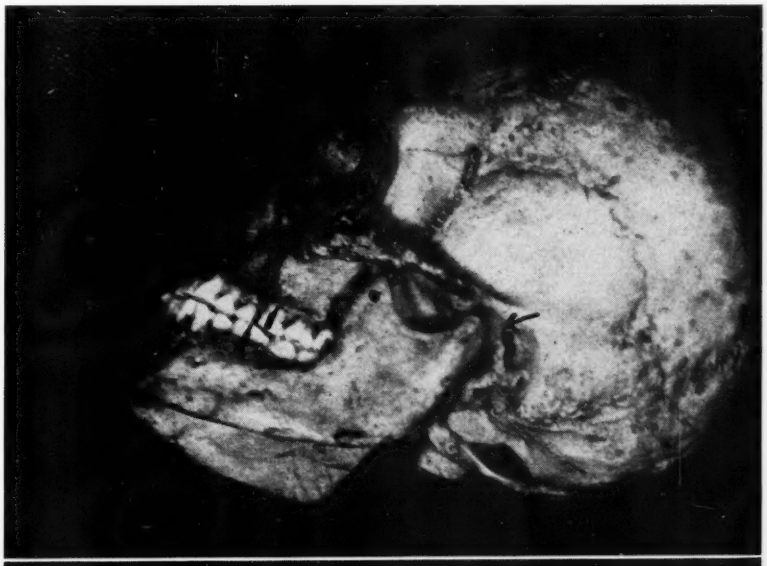

Fig. 2.

Fig. 1.—There is a thickening of the capsule and the condyle is forward on the subluxating side.

Fig. 2.—In the opposite side from the subluxation there is no space between the capsule and the condyle and the occlusion is altered.

fossa by the thickening of the avascular connective tissue, the articular disk, and the entire capsule. Rubber band traction is used to reduce the capsule swelling so that the condyles may resume their normal positions.

METHOD OF TREATMENT

A loop, about 3 mm. in diameter, is made of 0.014 stainless steel wire (fracture fixation wire). A second loop with a diameter of about 1.0 mm. is made immedi-

Fig. 3.

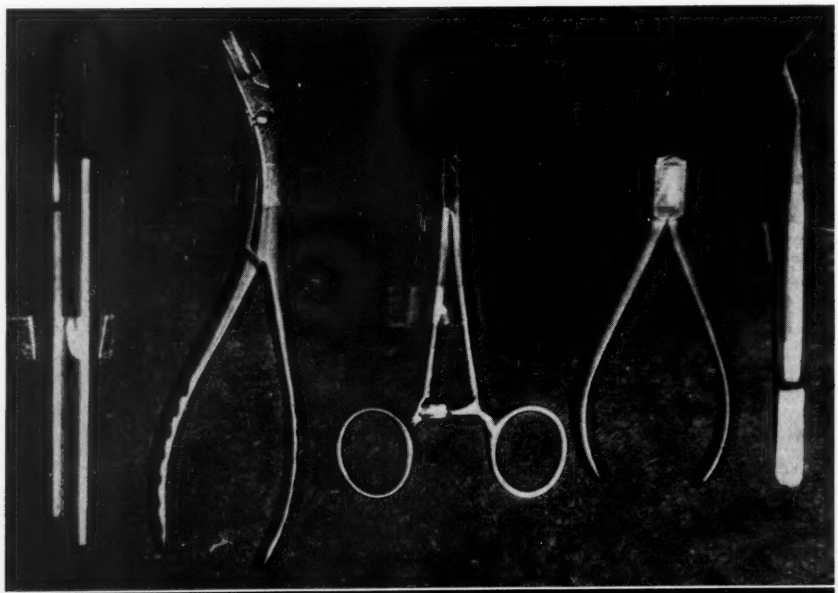

Fig. 4.

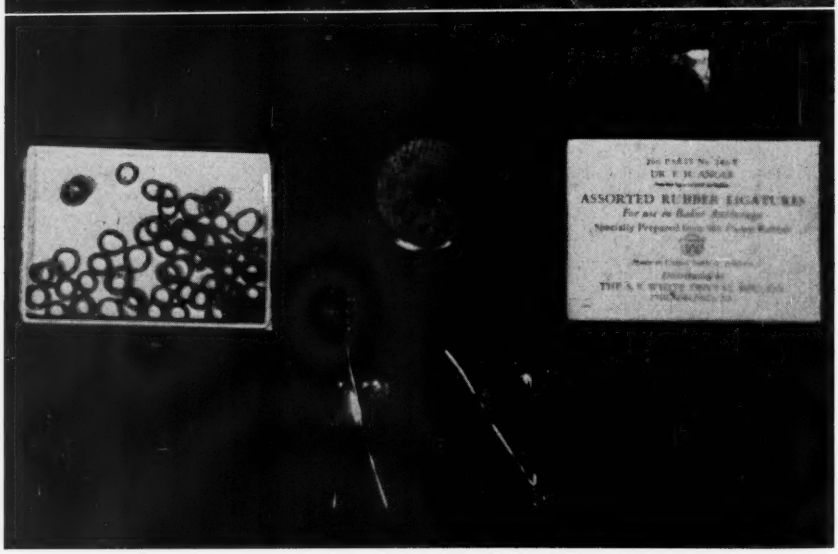


Fig. 3.—The instruments used for the preparation and placement of wire ligatures.
Fig. 4.—The wire loops have been prepared for placement in the mouth.

ately behind the first loop (Figs. 3 and 4). The ends of these wire loops should be long enough to encircle the upper first molar and second bicuspid. The ends are passed through the embrasure and around the two teeth, one end is passed through the small loop, and both ends are twisted tightly until the larger loop is held firmly between both teeth (Fig. 5). This same procedure is used on the lower teeth to attach loops to the cuspid and first bicuspid. When wires have been placed on both sides of the dental arches, and when the upper loops are turned upward and the lower loops are turned downward, a rubber band of from ½ to 1 pound pull is placed between them (Fig. 6). Any teeth may be used as retainers, providing tension on bands gives the recommended backward and upward pull.

At the end of 24 hours, the patient will have increased the vertical opening of the jaws by about 50 per cent with practically no pain. Within 2 to 4 days the

Fig. 5.

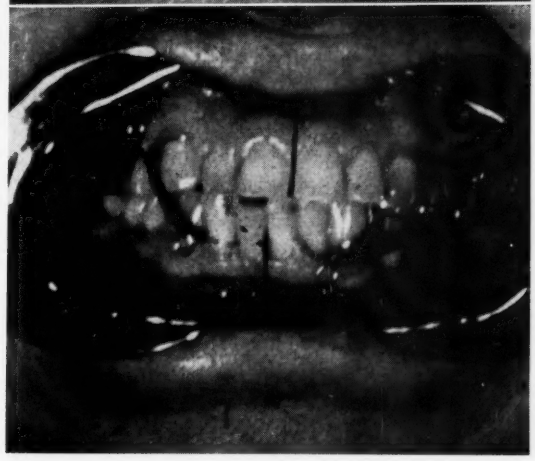

Fig. 6.

**Fig. 5—The wire ligatures are in place on the teeth. Note the deviation of the mandible to the right.**

**Fig. 6.—Rubber bands are used to supply the traction and are placed between the loop on the wire ligatures. Note that the deviation, as seen in Fig. 5, has been reduced to normal.**

discrepancies of the median line and the occlusion are considerably reduced and sometimes entirely corrected (Figs. 5 and 6). Traction is continued for 10 to 14 days until opening is normal with no deviation toward the opposite side that had been partially subluxated (Figs. 7 and 8). Roentgenograms made at this time show both condyles in their correct anatomic position, i.e., with equal spacing on both sides between the anterior, superior, and posterior surfaces of the glenoid fossa.

In some instances there are some remaining slight disturbances when the traction is removed after 14 days. Reapplying traction for another 5 to 6 days after an interval of about 6 days will relieve the remaining complaints.

Fig. 7.

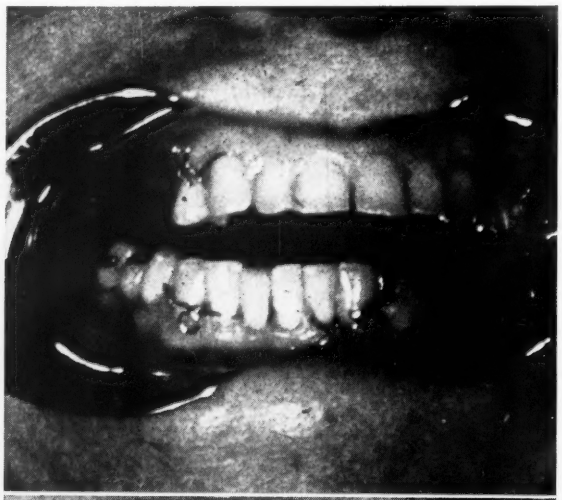

Fig. 8.

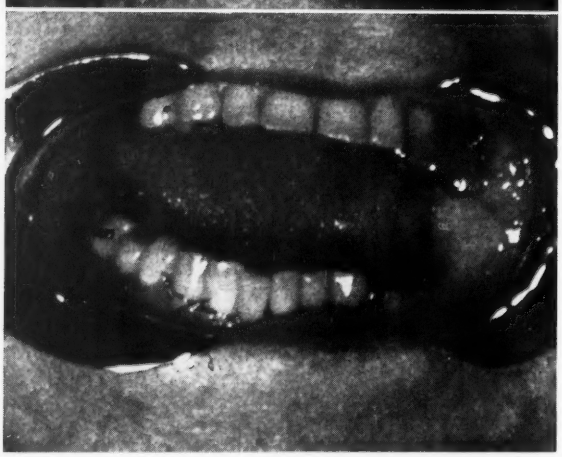

Fig. 7—The mandible deviates toward the side opposite from the partial subluxation and the opening is limited (before treatment).

Fig. 8.—There is no deviation upon opening after the traction has been applied for from 10 to 14 days.

SUMMARY

A method of treatment for temporomandibular joint disturbances by means of traction has been described. In 52 patients, the histories have been almost identical, with the exception of the intrinsic or extrinsic causes. Cuspal interference was corrected where it existed after treatment was completed. There have been no recurrences in those patients that we have been able to recheck periodically during the 5½ years we have used this method of treatment.

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820 Eleventh and L Bldg.
Sacramento 14, Calif.

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# *FIXED PARTIAL DENTURES*

## ANATOMIC CAST CROWN REPRODUCTION

T. S. MALSON, D.D.S.
*Cleveland, Ohio*

THE FAILURE OF RESTORATIONS to reproduce individual tooth form is one of the contributing factors in the etiology of periodontoclasia. This failure to re-establish the correct form of the tooth, particularly the marginal groove in the middle of the mesial and distal borders of posterior teeth, means that the occlusal, buccal, and lingual embrasures, which, in general, determine the correct contact areas, are in malrelation to the gingival tissues. This malrelation deprives the gingival tissues of the stimulating massage which is provided by the deflection of food during mastication.

There are times when it becomes necessary to use a functioning tooth as an abutment for the construction of a fixed or removable prosthesis. A clasp type of removable prosthesis may be giving satisfactory service but, because of caries, it becomes necessary to restore an abutment tooth.

The cast crown is the strongest type of restoration. The consideration for the periodontal tissues suggests that the tooth form be preserved. If the satisfactory functioning of the clasp type of prosthesis is to continue, the size, form, and position of the abutment tooth must be reproduced accurately in order that the relations of the occluding teeth are not changed. These are two of many reasons why the tooth form must be reproduced accurately in the cast gold crown.

### TECHNIQUE

If part of the tooth form has been lost, it is restored in the mouth with gutta-percha or cement. A split-tray impression is made of the tooth to be reproduced. At least one-half inch of the gingivae buccal and lingual to the tooth, as well as the teeth or gingivae anterior and posterior to the tooth, is included in the impression (Fig. 1).

The impression material should be one of the resin impregnated plasters, such as Truplastic. These impression materials are strong and do not distort appreciably when they have set and dried.

### IMPRESSION

The impression plaster is mixed to as heavy a consistency as will permit a good, clear-cut impression of the tooth and the adjacent gingival tissue. The split tray

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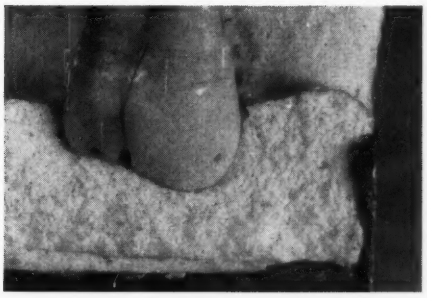

Fig. 1.—An impression of the tooth to be reproduced is made in a split tray.

Fig. 2.

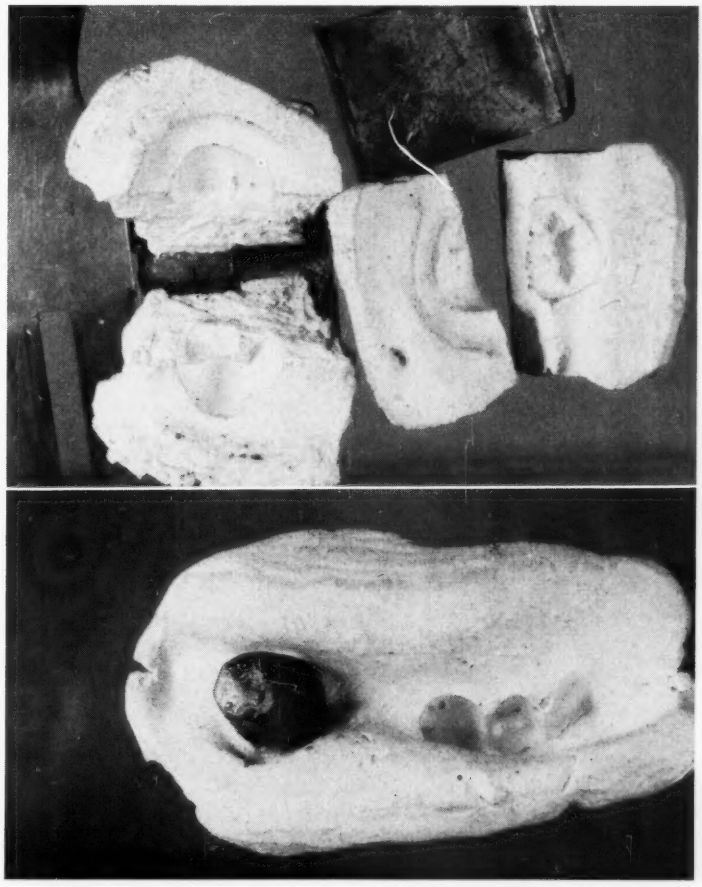

Fig. 3.

Fig. 2.—The split-tray impression is laid aside for later used.
Fig. 3.—The die is placed in a copper-band impression in the plaster impression and a cast is poured.

is placed in the mouth so that no part of the tray is in contact with the soft tissue. This is important, as it is necessary to refit this impression on a cast of the same region later on. The impression must have sharp detail of the tooth and tissue and it must be strong. It is laid aside for future use (Fig. 2).

The tooth is prepared for a full cast crown, using the method of choice. An individual modeling compound and copper-band impression of the prepared tooth is made for the purpose of constructing a die. A second impression of the prepared tooth is made in a copper band with inlay wax or modeling compound. While this copper-band impression is on the prepared tooth, a second plaster impression is made, being careful that the tray does not contact the tissue at any point. The previously prepared die is placed in the inlay wax or compound impression in the band (Fig. 3), and a cast is poured in stone. Provision must be made so that the die can be removed.

If a hydrocolloid, rubber base, or silicone impression technique for inlays and crowns is preferred, the working cast of the prepared tooth and the surrounding tissues may be secured from one impression. A good working cast of the prepared tooth and an accurate relation to the approximating tooth or teeth, as well as at least one-half inch of the buccal and lingual gingival tissue, are essential.

## FITTING THE IMPRESSION

When the cast has set, the first plaster impression made in the split tray is tried on the cast for fit. Quite often, because of a defect on the cast surface or a difference in the tone of the soft tissues at the time the two impressions were made, the split-tray impression will not fit the cast of the soft tissues accurately.

To correct this error, the soft tissue surface of the cast is marked with a soft pencil (Fig. 4), and the split-tray impression is tried for fit. Wherever there is a discrepancy, the pencil marking will be transferred to the impression. The pencil markings are scraped from the impression, and this procedure is repeated, if necessary, until the impression fits the cast accurately (Fig. 5).

## EQUIPMENT

The only additional equipment that is needed for this technique is two small "C" clamps and two soft rubber-headed tacks. A hole is drilled through the lower platform of the "C" clamp with a No. 3 round burr to hold the rubber-headed tack in place (Fig. 6). The tack allows continuous pressure to be applied when the "C" clamp is tightened.

## SECURING THE WAX FORM

The cast and the split-tray plaster impression are lubricated with a light oil. A strip of pink casting wax, about ½ inch by 1½ inch, is warmed over a Bunsen flame, folded, and roughly adapted over the die of the prepared tooth (Fig. 7). No attempt is made to fit or contour the wax. While the wax is still warm, the split-tray impression is placed on the cast in its *approximately* correct position. One "C" clamp is placed so that the jaws are on the metal of the buccal and lingual

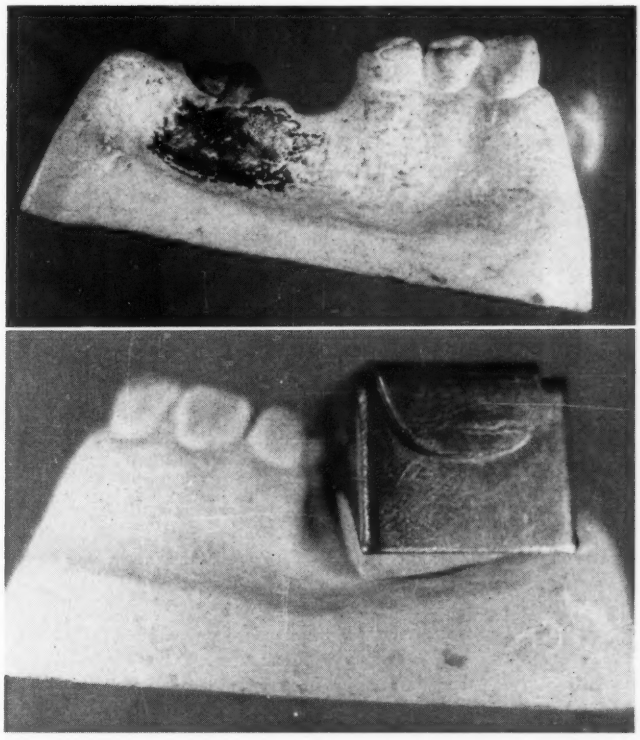

Fig. 4.

Fig. 5.

Fig. 4.—The cast is marked with pencil to locate discrepancies between the cast and the split-tray impression.

Fig. 5.—The split-tray impression is adjusted to fit the cast accurately.

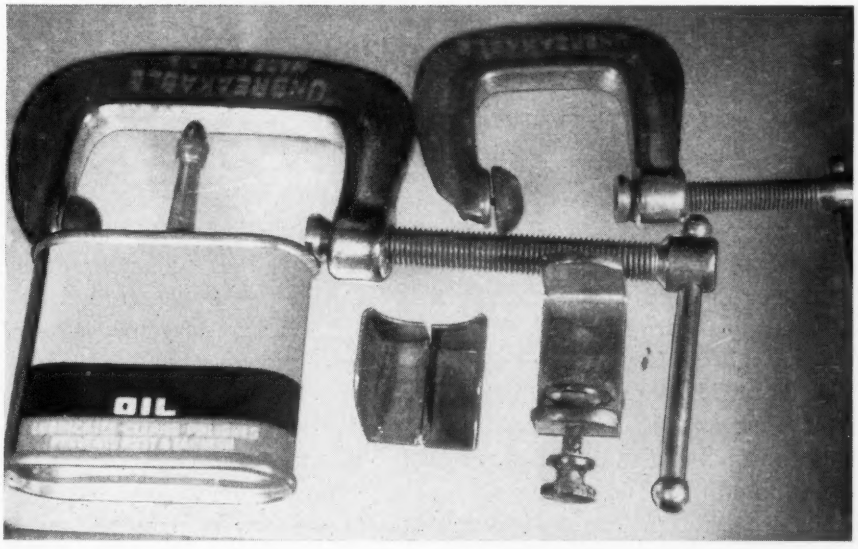


Fig. 6.—Two "C" clamps and two soft rubber-headed tacks are necessary to hold the split-tray impression correctly in place.

surfaces of the tray so it will close the split-tray impression when pressure is applied. The other "C" clamp is placed with one jaw on the top of the tray holding the split-tray impression, and the other jaw is placed directly under the root or handle of the die in the stone cast. This clamp will force the plaster impression toward the cast when pressure is applied (Fig. 8).

Fig. 7.

Fig. 8.

Fig. 7.—Softened pink casting wax is adapted over the die.
Fig. 8.—The two "C" clamps force the split-tray impression to place in the cast, and the wax is thus contoured to the correct form.

The stone cast, with the approximating split-tray impression, and the two "C" clamps are placed in a warm water bath (about 105° F.) for about 1 minute, so as to allow the heat to penetrate the cast and impression. Pressure is then applied by slowly closing the "C" clamps until there is a perfect apposition of the impression with the stone cast. The pressure is started toward the cast first, and *then* the impression is forced together from the sides.

When the impression and cast are in apposition, the assemblage is removed from the warm water bath and placed on the laboratory bench to cool. It is *not chilled* in cold water.

When cool, the "C" clamps and split-tray impression are removed, and a wax reproduction of the original form of the prepared tooth, plus a very thin fin of wax where the two halves of the plaster impression were forced together, is developed.

The die and the wax form of the crown are removed together from the cast. The wax crown is loosened from the die at once and replaced. The thin fin of excess wax is removed with a dull plastic instrument or wax carver.

When the wax crown form is completed, it is sprued and invested for casting at once. A careful casting technique will give a finished crown that requires adjusting only where the sprue pin is attached (Figs. 9-12).

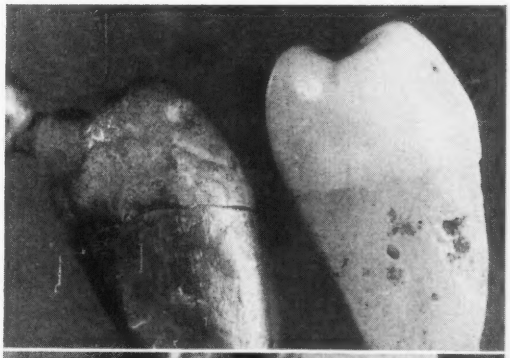

Fig. 9.

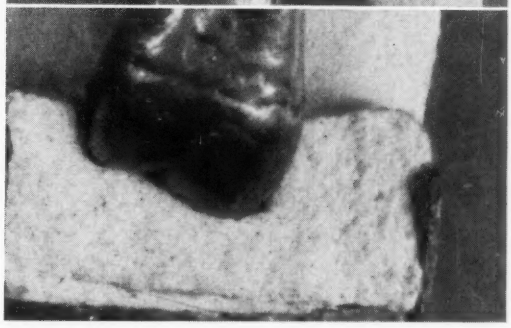

Fig. 10.

Fig. 9.—The finished crown is identical in form with that of the natural tooth.
Fig. 10.—The finished crown fits into the split-tray impression of the natural tooth indicating the similarity of form.

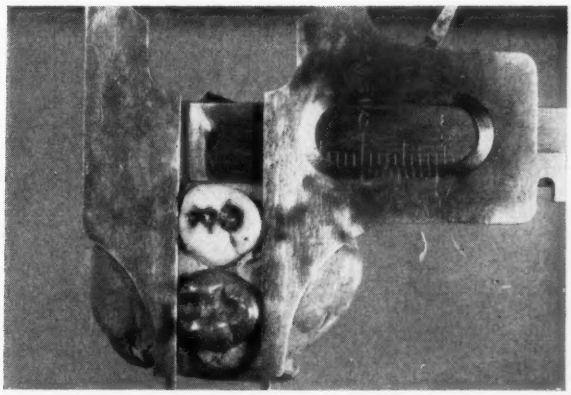

Fig. 11.—The casting exhibits dimensional accuracy when it is compared with the natural tooth.

SUMMARY

A procedure for the construction of cast crowns that reproduce the external form of the natural tooth accurately has been described (Fig. 13). The advantages of this procedure are: (1) the outer form of any tooth can be reproduced accurately so as to fit into the original split-tray impression of the tooth, (2) the laboratory procedures may be delegated to a careful assistant, (3) the need for carving to simulate natural tooth form is eliminated, (4) the time required to refit clasps when a removable denture is involved is eliminated, (5) the maintenance of the natural tooth form and its relation to the gingival tissue lessens the irritation so often found about the gum tissue of full cast crowns, (6) the health of the periodontal tissues is preserved, and (7) the technique may be used for the construction of either full or three-fourth cast crowns.

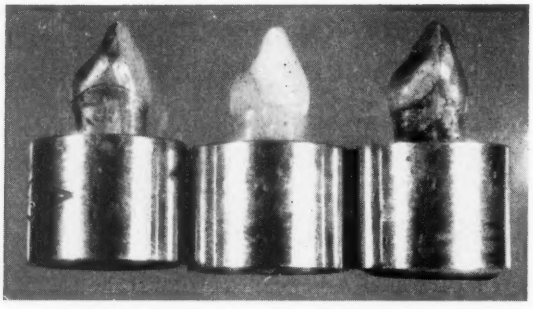

Fig. 12.—The procedure may be used for three-fourth or veneer crowns.

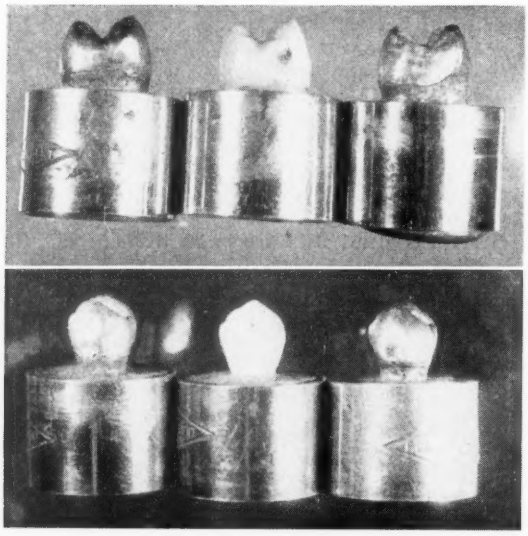

Fig. 13.—The external form of clinical crowns can be duplicated in cast restorations.

1038 Keith Bldg., Cleveland 15, Ohio

# PREPARATION FOR AND CONSTRUCTION OF BAKED PORCELAIN CROWNS AND INLAYS

THOMAS B. SHARP, D.D.S.*
*Emory University, School of Dentistry, Atlanta, Ga.*

THE PARAMOUNT REASON FOR the use of restorations of fused porcelain is its natural esthetic quality. It more closely simulates the appearance of tooth enamel than any other material, with color and form remaining constant. The inherent weakness of porcelain lies in its friability; therefore, usage in full coverage is limited to the anterior teeth in favorable incisal relationships. Vacuum-fired porcelain has increased the strength and improved the color saturation, hue, and brilliance over the usual baked porcelain.

Porcelain inlays are used in Class III and V cavities, principally, when esthetic factors are of prime importance. Class IV cavities may be restored with porcelain inlays, but usually jacket crowns are more practical.

## TREATMENT PLANNING

The diagnosis for porcelain crowns begins with a visual clinical examination. The eight upper anterior teeth are the usual concern of the youthful and intermediate age groups.

Disfigurement may be produced by unsightly diastemas and peg-shaped teeth (often lateral incisors). When these exist, well-formed, normal central incisors may be present with a 1.0 mm. diastema at the median line. The peg lateral incisors are dwarfed by comparison, and each may have a considerable diastema mesially and distally. The median diastema may be closed in 2 or 3 days with orthodontic rubber bands around the two central incisors and secured with gold ligature wire. The lateral incisors can be prepared, and jacket crowns constructed, establishing the mesial and distal contacts. The distal contacts would be high, at the gingival ⅓ of the tooth, permitting a very slight but delicate diastema to appear in the incisal curve. The superior labial frenum attached at the gingivae usually atrophies under the pressure created by the continuous contacts of the six anterior teeth, and rarely is it necessary to have it removed surgically.

Other causes of disfigurement are: (1) extensive caries and/or weakened restorations involving the incisal angles, (2) pitted and hypoplastic enamel resulting from eruptive fevers and childhood diseases, (3) unsightly gold restorations, (4) discolored teeth from devitalization, (5) mottled enamel from endemic fluorosis, (6) traumatic injuries, or fractures, and (7) malposed teeth.

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*Associate in Clinical Crown and Bridge Dentistry.

Consideration is given to the possibility of adult orthodontic treatment to improve the positions of malposed or rotated teeth.

The anterior incisal edge relationship is checked visually in the centric, protrusive, and lateral occlusal positions, and the possibilities of equilibration of the posterior occlusion to eliminate anterior protrusive thrusts are evaluated. Often the removal of premature contacts in centric occlusion will produce clearance and freedom from trauma on the anterior teeth. Extensive occlusal reconstruction and posterior occlusal replacements should be completed prior to the rehabilitation of anterior teeth.[1]

A critical examination of the gingival tissues for hypertrophy, atrophy, avitaminosis, calcareous deposits, or poor oral hygiene is made.

Vitality tests of the teeth, roentgenograms to determine the size and location of the coronal portion of the pulp and presence of periodontal lesions, and study casts of both dental arches are made. The gingival tissues should be restored to health before multiple teeth are prepared for anterior jacket crowns.[2]

A photographic record should be made before treatment is begun. These records should show a close-up of the teeth in one exposure and a smiling full face portrait in another.

## SEDATION AND ANESTHESIA

A capsule containing ¾ grain Nembutal is administered to the patient 30 minutes prior to the start of operative treatment. Infiltration anesthesia suffices for the upper eight anterior teeth. An effective nontoxic topical anesthetic is used on the labial mucous membrane. A 27-gauge, 1-inch needle with a long hub is used to slowly inject 0.5 c.c. Ravocaine HCl. 0.4 per cent and Novocaine 2 per cent with Levophed 1 :30,000. The glass cartridge containing the solution is heated gently so its temperature would approximate body temperature. A single injection is made over the apex of each tooth involved. The tissues on the lingual side of the tooth are anesthetized by injecting from the labial side straight through the interdental papillae. Then the palatal injection may be made painlessly.

## PREPARATION OF TEETH

The incisal edges of the eight upper anterior teeth represent the "smiling line," and consideration of this is made on the study casts for grinding these teeth to improve their esthetics. The incisal edges are shaped to conform with the proposed porcelain restorations, in accordance with the age and sex of the patient. The central incisors should be longer than the laterals in a youthful person. A feminine or delicate effect is achieved by rolling the mesioincisal angle of the lateral incisor slightly and rounding the distoincisal angle. The cuspids are often shortened and rounded to follow the curve created by the upper border of the lower lip when smiling.

For a masculine effect, the incisal angles would be ground to produce a square or flattened edge, following the same basic elliptical curve.

The production of gentle diastemas between the cuspid and lateral incisor

teeth is esthetically sound. In porcelain jacket restorations, this will avoid the "block of porcelain" look. A preliminary color and shade selection is made.

All instruments to be used are selected and placed on a sterile tray. A planned sequence of procedure is essential, and all cuts are completed with each instrument before it is discarded. By this procedure, the time of preparation will be reduced to a minimum, and less injury to the pulp or gingival tissues will result.

## INSTRUMENTATION

The objective is to reduce the bulk of the tooth in such a manner that the resultant crown will be of uniform thickness, on a smooth, definite shoulder.[3] The half-moon fractures occurring in the gingival third of porcelain crowns are minimized by a uniform thickness of about 1.0 mm. including the shoulder on a normal tooth. This will protect the pulp and increase the strength of the crown and its resistance to stress.

The method of instrumentation to be described can be used for preparing any of the eight upper anterior teeth.

1. Mesial and distal slices are made with high rotational speed and light pressure by means of a ¾ inch perforated diamond edge cutting disk. The proximal shoulders are established with this instrument, and the shoulders are carried through toward the lingual surface. The disk is moved toward the labial surface as far as the approximating tooth will permit this movement, without injury. A steady stream of tepid water is kept on the rapidly revolving instrument at all times. The same disk is used to serrate the enamel of the labial surface to the desired depth.
2. A diamond wheel stone, 9 mm. in diameter and 1.5 mm. thick, is used to cut the incisal edge and the lingual and serrated labial surfaces to the desired depth
3. A 4 mm. edge and face cutting diamond stone is used in the contra-angle handpiece to remove enamel near the gingivae and to connect the proximal shoulders with those of the labial and lingual surfaces.
4. A coarse sandpaper disk, ¾ inch in diameter, is used in the contra-angle handpiece to round all line angles.
5. The shoulders are refined by using a No. 57 or end cutting bur. The continuous shoulder should flare apically, as a gross bevel, away from the long axis of the preparation. It is finished with a scraping action of a small biangle chisel, at right angles to the prepared shoulder.

## SELECTION OF COLOR AND SHADE

The preliminary color and selection shade which was recorded is disregarded. A new selection of color saturation, hue, and brilliance is made, and the two, possibly different, selections are correlated for final acceptance. A dentist's judgment of color and shade may vary from time to time, and it is well to recheck. Shades should be selected in the best possible light, with daylight preferable. Natural teeth lighten a shade or more when dry, so selections should be made before the teeth are isolated or washed free of clinging or viscous saliva, which influences light refraction.

IMPRESSION

A copper band of the right size is selected and annealed. The band is festooned with crown scissors to the contour of the gingivae, and the outside edge is polished with a sandpaper disk. A No. ½ round bur is used to perforate the band at the gingival margin on the labial and lingual sides about 2 mm. from the edge. This will permit air to escape as the modeling plastic is compressed into the band when it is in position.

The band is placed over the tooth, from the lingual toward the labial surface, with gentle pressure. Red modeling plastic is softened over dry heat and allowed to cool momentarily. The cone-shaped impression material is touched to cocoa butter to prevent it from sticking to the tooth structure. The cone of modeling plastic is directed into the copper band and pressed to place. It is chilled with at least two rubber bulb syringes of cold water. This impression is carefully removed and laid aside for making the metal die.

Another copper-band impression is made just as accurately and allowed to remain on the tooth. A plaster of Paris impression of all of the anterior teeth is made, including the band. An alginate impression of the lower teeth is made, and then a centric interocclusal record is made in wax. An amalgam die is cast in the first copper-band impression. When the amalgam has set, the root portion of the die is trimmed to a tapered, hexagonal shape. The root of this die is lubricated, and the die is placed in the modeling plastic impression fixed in the plaster impression, and the master cast is formed of stone. The lubrication of the die facilitates its easy removal from the hardened stone. The upper and lower stone casts are oriented on a small articulator according to the interocclusal record.

CARE OF PREPARED TOOTH

The tooth is isolated and bathed in eugenol and 3 per cent trichloracetic acid solution. This is dried off and Copalite varnish painted over the entire preparation to protect the pulp.

A temporary crown is made of tooth color gutta-percha and set with sedative cement.

Self-activated tooth color resins, or silicate cements, may be fashioned in copper bands or celluloid crown forms for longer use, when necessary. Either of these materials should be removed from the tooth when the initial set begins, and its heat allowed to dissipate; then it is trimmed, and set with a sedative cement. It is expedient to avoid producing temporary crowns that are too flattering.

BAKING PORCELAIN JACKET CROWN

A closely adapted matrix, which is extended well over the shoulder, is made from dead soft or highly annealed 0.001 platinum foil. A tight tinner's joint on the lingual side is essential. The shade selected is referred to the porcelain chart for the proper base and enamel powders. The base shade is mixed thoroughly with distilled water on a glass slab. This is applied to the matrix and condensed well by vibration. The wet porcelain is trimmed away from the shoulder area to permit

the porcelain to shrink without distorting the matrix during firing. The matrix is removed from the die, placed in the furnace with an accurate pyrometer, and carried to a high biscuit bake. It is removed and allowed to cool slowly. After replacing it on the die carefully, the exposed matrix is reburnished. Additional base shade porcelain is placed in the shoulder area. The enamel shade is added over all and overbuilt before it is fired in the vacuum furnace. The crown is carried slowly to a 2,400° F. bake, removed to the open furnace door, and allowed to cool slowly. It is placed back on the die and trimmed with coarse disks, stones, etc., to the anatomy indicated by the adjacent teeth on the stone cast. On the return of the patient, the crown is placed in position, and all detailed carving is refined. The contact areas are kept well toward the lingual surface for the production of a third dimensional illusion of depth. The protrusive and all eccentric occlusal positions are checked in the mouth for the avoidance of trauma.

The crown is removed, cleansed thoroughly, and returned to the furnace for glazing. After slow cooling to further temper the porcelain, the platinum matrix is removed.

## PORCELAIN INLAYS

Porcelain inlays are used only in Class III, V, and sometimes Class IV cavity preparations.

The preparation is made deeper than that for a gold inlay, and the margins are not beveled. A No. 6 round bur is used to develop the outline form of the cavity. A No. 559 cross-cut fissure bur is used to form the walls of the cavity. A tapered diamond stone is used to refine the cavity walls.

## IMPRESSION

A copper band is cut to envelop the shape or location of the preparation, and annealed. Modeling plastic is softened over dry heat, allowed to cool momentarily, touched to cocoa butter to prevent sticking, and pressed into the cavity. It is chilled with cold water and removed.

An amalgam die large enough to permit adaptation of the platinum foil is cast with several millimeters of excess flash.

## BAKING THE PORCELAIN INLAY

The same essential procedure is followed as for a jacket crown. The dead soft 0.001 platinum foil is well adapted, using a shaped art gum eraser and ball and wing burnishers. The base shade of porcelain mix is condensed thoroughly and trimmed away from the margins. After the high biscuit bake, the platinum margins are reburnished, and the base shade of porcelain is added just short of the margins. The enamel shade is added and overbuilt. The inlay is carried slowly to 2,400° F. and allowed to cool slowly. It is returned to the die, contoured with disks and stones, and returned to the furnace for glazing, after which the foil matrix is removed.

## CEMENTATION OF PORCELAIN RESTORATIONS

The internal surface of porcelain jackets and inlays may be etched for greater adhesion of cement. The margins and shoulders are protected with wax, and a small cotton applicator wet with hydrofluoric acid is touched to the interior surface of the crown or the cavo walls of the restoration. The acid is counteracted immediately with a sodium bicarbonate solution. A slightly etched surface will result. The restoration is cleansed thoroughly with soap and water, dried, acidified with zinc cement liquid, washed in clear water, and dried.

Before cementation of a crown in a situation where there is little interdental clearance, it is of value to remove the glaze from the lingual surface with coarse, soft rubber wheels or fine sandpaper disks. This will permit slight attrition of the opposing tooth to occur if vulnerability develops from the elongation of teeth.

A selection of 2 or 3 shades of oxyphosphate of zinc cement powders is mixed with distilled water, singly and in combination, and placed in position until the color refraction of the crown is satisfactory.

The tooth preparation is isolated and cleansed with a solvent for copal resin. A fresh coat of thin Copalite is applied. This not only protects the pulp, but greatly improves the tenacity of the cement.

The selected shade or shades of cement powder are mixed with its proper liquid to a very thin consistency, and the restoration is gently vibrated to position.

## SUMMARY

1. Fused porcelain crowns and inlays, when indicated, are the most esthetically satisfactory of any restorative material available for anterior teeth since they possess stability of color and form.

2. A planned sequence of procedure is essential if discomfort is to be eliminated for the patient and efficiency is to be increased for the dentist. The combination will result in more accurate preparations and restorations.

3. Vacuum furnace-fired porcelain, thoroughly condensed in molding, produces the closest apposition of the powder grains, free from air and subsequent bubbles. A superior porcelain restoration combines strength and esthetics.

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106 Forrest Ave., N. E.
Atlanta, Ga.

# A PRACTICAL MANDIBULAR ANTERIOR PONTIC

WILFRED D. WHITESIDE, D.D.S.
*Corpus Christi, Texas*

THE LOWER ANTERIOR FIXED partial denture probably presents more problems to the dentist than any other fixed prosthesis. Sanitation is a major problem. The lingual surfaces of the lower anterior teeth are difficult to reach with a toothbrush, and because of the sublingual salivary ducts, the restoration is constantly plagued by calculus. The direction from which occlusal forces are applied to the lower anterior fixed partial denture is important too. The normal occlusal relationships demand that the portion of a lower anterior pontic, which is subjected to the forces of occlusal contact, must be esthetically pleasing.

An appropriate solution to these problems seems to lie in the porcelain fused to metal pontic.[1] However, the demands that this technique places upon the laboratory technician and the difficulty involved in repairing a fractured pontic are definite disadvantages.

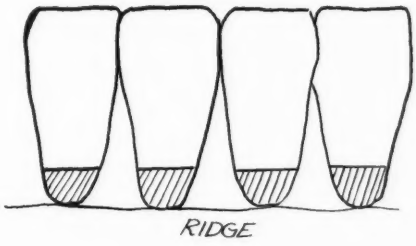


Fig. 1.

Fig. 2.

Fig. 1.—The labial view of lower anterior pontics utilizing Steele's interchangeable facings. Note the wide gingival embrasures and the single point of contact of the gold backing with the mucosa.

Fig. 2.—A single pontic as seen from the mesial surface. The form of the gold backing provides support for the porcelain.

The acrylic resins, despite their continued improvement, are not entirely satisfactory. They are too soft, porous, and dimensionally unstable to meet the requirements of an ideal pontic material.

Pontics which solve the problems and fulfill the basic requirements of pontics for the lower anterior region are made by utilizing Steele's interchangeable facings (Figs. 1 and 2).

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A pontic of this design has the following advantages: (1) The gingival portion is shaped like the tapering end of an egg. This form is considered ideal for lower posterior pontics,[2,3] and it has the same advantages when it is used in lower anterior regions. (2) The porcelain is supported by metal placed at right angles to the occlusal forces which are exerted upon it. (3) The facing is replaceable. (4) The pontic is economically and easily fabricated.

## SUMMARY

A more hygienic type of lower anterior pontic using Steele's facings is suggested.

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Suite 2536 Medical Center
Corpus Christi, Texas

# REACTION OF THE HUMAN DENTAL PULP TO CAVITY PREPARATION

## Part II. At 150,000 R.P.M. With an Air-Water Spray

HERBERT SWERDLOW, D.D.S.,* AND HAROLD R. STANLEY, JR., D.D.S., M.S.**
*Bethesda, Md.*

MANY NEW INSTRUMENTS CAPABLE of producing high rotational speeds are being introduced to the dental profession. Increased cutting efficiency and control of vibration are two of the most noteworthy clinical characteristics of rotary speeds over 100,000 r.p.m. Walsh and Symmons[1] reported that the most uncomfortable sensation of vibration was produced at a speed of 6,000 r.p.m., while vibrations produced at 60,000 r.p.m. were beyond the human threshold of perception. Inasmuch as considerable interest has been shown in higher rotational speeds, this second report† deals with the biologic response of human pulpal tissue to rotational speeds in excess of 100,000 r.p.m. The instrument used was a belt-driven contra-angle handpiece in which conventional gears have been eliminated, thus helping to reduce the frictional heat problem and the need for constant lubrication. The cutting tool is mounted on a 1/16 inch smooth shank which has a frictional fit in a rubber chuck. This rubber bushing helps to dampen some of the vibration from the drive mechanism as well as from eccentricities present in the burs.

### MATERIALS AND METHODS

Noncarious, noninfected vital teeth to be extracted for periodontal and prosthetic reasons were selected for study. A total of 53 teeth were treated and removed from 8 patients, whose ages ranged from 33 to 45 years (average 38.0 years). Typical Class V cavity preparations were cut in the gingival region of the facial surfaces of all teeth with an inverted cone No. 35 tungsten carbide bur rotating at 150,000 r.p.m. When speeds in excess of 100,000 r.p.m. are employed, tungsten carbide burs have proved to be more efficient clinically than diamond stones.‡

The depth and outline form of each cavity preparation were similar for each morphologic type of tooth as dictated by clinical experience. The handpiece speed

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*Clinical Center, Dental Department, National Institutes of Health, Public Health Service, U. S. Department of Health, Education, and Welfare, Bethesda 14, Md.
**National Institute of Dental Research, National Institutes of Health, Public Health Service, U. S. Department of Health, Education, and Welfare, Bethesda 14, Md.
†Report I. Effect of Water Spray at 20,000 R.P.M., J.A.D.A. 56:317-320, 1958.
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TABLE I. HISTOLOGIC FINDINGS

| SPECIMEN NUMBER | TOOTH | AGE AND SEX | PREPARATION TIME IN SECONDS | TIME INTERVAL IN DAYS | APPROXIMATE THICKNESS OF REMAINING DENTINE (MM.) | | INCIDENCE OF AN INFLAMMATORY CELL EXUDATE | |
|---|---|---|---|---|---|---|---|---|
| | | | | | DIRECT MEASUREMENT | TUBULAR MEASUREMENT | INTENSITY −, +, ++, +++* | DECREASING ORDER OF CELLS<br>MONOCYTES (M)<br>LYMPHOCYTES (L)<br>NEUTROPHILS (N)<br>PLASMA CELLS (P)<br>EOSINOPHILS (E) |
| 1 | 1\| | 34—M | 15 | Immediate† | 0.14 | 0.21 | − | − |
| 2 | 2\| | 34—M | 10 | Immediate† | 0.39 | 0.43 | − | − |
| 3 | \|3 | 36—M | 25 | 2 | 0.93 | 1.14 | + | M |
| 4 | \|2 | 36—M | 20 | 2 | 0.39 | 0.50 | + | M |
| 5 | \|1 | 36—M | 17 | 2 | 0.39 | 0.43 | + | M,N |
| 6 | 1\| | 36—M | 18 | 2 | 0.43 | 0.50 | + | M,L |
| 7 | 2\| | 36—M | 15 | 2 | 0.61 | 0.71 | ++ | M,L,N |
| 8 | 3\| | 36—M | 19 | 2 | 0.81 | 1.07 | ++ | M,L,N |
| 9 | 7\| | 42—F | 24 | 5 | 1.50 | 1.86 | − | − |
| 10 | 4\| | 42—F | 14 | 5 | 0.79 | 0.86 | <+ | M,L |
| 11 | \|3 | 39—F | 12 | 16 | 1.07 | 1.50 | + | M,L |
| 12 | \|2 | 39—F | 11 | 16 | 1.21 | 1.86 | + | M,L |
| 13 | \|1 | 39—F | 11 | 16 | 1.14 | 1.36 | ++ | M,L |
| 14 | 3\| | 33—M | 12 | 27 | 1.50 | 2.00 | − | − |
| 15 | 4\| | 33—M | 10 | 27 | 0.93 | 1.21 | + | M,L |
| 16 | 7\| | 33—M | 15 | 27 | 2.43 | 2.71 | − | − |
| 17 | \|7 | 39—F | 11 | 30 | 1.57 | 2.00 | <+ | M,L |
| 18 | \|4 | 39—F | 8 | 30 | 0.24 | 0.36 | − | − |
| 19 | 1\| | 39—F | 10 | 30 | 1.07 | 1.36 | − | − |
| 20 | 2\| | 39—F | 11 | 30 | 1.21 | 1.71 | − | − |
| 21 | 3\| | 39—F | 11 | 30 | 1.00 | 1.43 | − | − |
| 22 | 7\| | 36—F | 27 | 37 | 1.21 | 1.57 | − | − |
| 23 | \|3 | 36—F | 12 | 37 | 0.79 | 1.00 | − | − |
| 24 | \|2 | 36—F | 8 | 37 | 0.71 | 0.86 | <+ | L,M |
| 25 | \|1 | 36—F | 8 | 37 | 0.71 | 0.79 | − | − |
| 26 | 1\| | 36—F | 8 | 37 | 0.64 | 0.79 | − | − |
| 27 | 2\| | 36—F | 8 | 37 | 0.64 | 0.79 | − | − |
| 28 | 3\| | 36—F | 13 | 37 | 1.07 | 1.43 | − | − |
| 29 | \|3 | 39—F | 9 | 86 | 0.50 | 0.61 | − | − |
| 30 | \|2 | 39—F | 7 | 86 | 0.79 | 0.81 | − | − |
| 31 | \|1 | 39—F | 9 | 86 | 0.36 | 0.39 | ++ | M,L,N,E |
| 32 | 1\| | 39—F | 8 | 86 | 0.47 | 0.47 | − | − |
| 33 | \|4 | 36—F | 14 | 93 | 0.36 | 0.36 | <+ | M,L |
| 34 | \|8 | 36—F | 14 | 93 | 2.57 | 2.71 | − | − |
| 35 | \|3 | 33—M | 15 | 96 | 1.21 | 1.78 | − | − |
| 36 | \|2 | 33—M | 11 | 96 | 0.86 | 1.07 | <+ | M,L |
| 37 | \|1 | 33—M | 10 | 96 | 0.71 | 0.90 | <+ | M,L |
| 38 | 1\| | 33—M | 9 | 96 | 0.79 | 0.96 | − | − |
| 39 | 2\| | 33—M | 8 | 96 | 0.86 | 1.10 | + | P,M,L |
| 40 | 3\| | 45—M | 38 | 105 | 1.00 | 1.21 | − | − |
| 41 | 2\| | 45—M | 11 | 105 | 0.57 | 0.57 | − | − |
| 42 | 2\| | 39—F | 9 | 107 | 0.64 | 0.61 | − | − |
| 43 | 3\| | 39—F | 11 | 107 | 0.71 | 0.81 | <+ | L,M |
| 44 | 4\| | 39—F | 7 | 107 | 0.57 | 0.71 | − | − |
| 45 | 5\| | 39—F | 13 | 107 | 0.79 | 0.96 | − | − |
| 46 | 3\| | 42—F | 20 | 123 | 0.71 | 0.81 | <+ | M |
| 47 | 2\| | 42—F | 13 | 123 | 0.21 | 0.21 | +++ | L,M,P,N,E |
| 48 | 1\| | 42—F | 12 | 123 | 0.64 | 0.64 | + | M |
| 49 | \|1 | 42—F | 15 | 123 | 0.57 | 0.64 | + | M |
| 50 | \|2 | 42—F | 10 | 132 | 0.57 | 0.57 | − | − |
| 51 | \|1 | 42—F | 9 | 132 | 0.43 | 0.43 | − | − |
| 52 | 1\| | 42—F | 10 | 132 | 0.21 | 0.21 | +++ | L,M,P,E,N |
| 53 | 2\| | 42—F | 12 | 132 | 0.24 | 0.24 | + | P,M |

*The symbols −, +, ++, +++ represent progressively increasing degrees of pathologic alterations.
†Less than 1 hour.

| EDEMA<br>−, +<br>++, +++<br>* | INCREASED NUMBER OF CAPILLARIES<br>−, +, ++, +++<br>* | AMOUNT OF CELLULAR DISPLACEMENT<br>−, +, ++, +++<br>* | ODONTOBLASTIC LAYER<br>NORMAL (−)<br>DECREASED THICKNESS OF LAYER BUT NORMAL NUMBER OF CELLS (D)<br>AN ATROPHIC SINGLE CELL LAYER (A) | PREDENTINE AND DENTINE<br>UNIFORM AND EVEN (−)<br>DECREASED AND UNEVEN (D)<br>INCREASED IN WIDTH (I) | INTRANUCLEAR ODONTOBLASTIC VACUOLES<br>−, +, ++, +++<br>* | INTENSITY OF EOSINOPHILIC MATERIAL<br>−, +, ++, +++<br>* |
|---|---|---|---|---|---|---|
| + | − | − | − | − | − | − |
| + | + | − | − | − | − | − |
| + | + | + | D | − | − | − |
| + | ++ | <+ | D | − | − | − |
| ++ | + | ++ | D | − | − | − |
| + | + | <+ | D | − | − | − |
| ++ | ++ | ++ | D | − | − | − |
| ++ | ++ | ++ | D | − | − | − |
| + | + | <+ | − | − | − | ++ |
| + | + | <+ | D | D | − | − |
| + | + | − | − | − | +++ | − |
| + | + | − | − | − | +++ | − |
| + | +++ | + | D | − | − | − |
| + | + | − | D | − | ++ | − |
| + | ++ | − | A | I | − | − |
| − | − | − | − | − | +++ | − |
| + | + | − | − | − | − | − |
| + | + | − | D | − | − | − |
| − | − | − | − | − | − | − |
| + | + | − | − | − | ++ | ++ |
| + | + | − | − | − | +++ | − |
| + | + | − | − | − | + | ++ |
| + | + | − | D | − | <+ | − |
| + | ++ | − | A | I | − | − |
| − | ++ | − | D | − | − | − |
| + | − | − | − | − | − | − |
| + | + | − | D | − | − | − |
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| + | + | − | D | − | − | − |
| + | + | − | D | − | − | − |
| ++ | ++ | ++ | A | − | − | − |
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| + | + | − | D | − | − | +++ |
| + | + | <+ | D | − | <+ | +++ |
| ++ | + | + | D | D | − | − |
| + | + | <+ | D | − | − | − |
| ++ | ++ | <+ | A | D | − | ++ |
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| + | + | − | A D | − | <+ | − |
| + | + | − | D | − | <+ | − |
| + | + | − | A | I | − | ++ |
| + | + | <+ | A | I | − | − |
| + | + | − | A | I | <+ | + |
| + | + | − | A | I | − | +++ |
| + | + | − | D | D | − | + |
| + | ++ | − | D | − | − | − |
| ++ | + | + | A | I | − | − |
| + | − | − | A | − | − | − |

was kept constant and was checked frequently with a tachometer. One operator performed all the clinical work employing the same dental unit and handpiece.

All teeth were prepared with a continuous air-water spray and uniform pressure. A postal scale was employed frequently during cavity preparation to measure the approximate pressure at the cutting tool. Operating pressures were in the range of 2 to 4 ounces. Each preparation was finally air-dried and filled with zinc oxide and eugenol cement.

The teeth were removed under general anesthesia at intervals from less than one hour up to 132 days following cavity preparation (Table I). Extraction was accomplished by surgical excision (buccal flap) with careful application of the forceps to the root.

The specimens were fixed in 10 per cent formalin. In order to afford maximum penetration of the fixative, the fillings were removed from the teeth, and the root tips were cut off immediately following extraction.

After decalcification in 5 per cent formic acid, the teeth were washed, dehydrated, and imbedded in paraffin. Serial sections 6 $\mu$ thick were cut, and every other slide containing two or three sections was stained with hematoxylin and eosin.

All of the stained sections of each specimen were surveyed at ×35 with a calibrated grid in the ocular in order to find the section with the least remaining dentine (R. D.) between the floor of the cavity preparation and the pulpal surface. It is especially important to examine these sections, because previous studies have shown that the inflammatory response in the pulp is greatest in the area where the floor of the cavity preparation is closest to the pulp. Descriptive emphasis was placed on the microscopic findings in these selected sections. Less severe reactions could be found in areas where the R. D. measurement was greater, but these latter findings were not recorded. Because an inflammatory exudate was not usually found in the "less than one hour" specimens[2] due to insufficient time lapse, the R. D. measurements in Table II do not include the "immediate" specimens. The histologic findings and other pertinent data are tallied in Table I. The symbols −, +, ++, and +++ represent progressively increasing degrees of pathologic alterations.

Van Huysen* has suggested that the actual length of the dentinal tubules beneath the cavity preparation might be more closely related to the inflammatory response than a direct measurement of the remaining dentine which does not take into account the increased length of tubules due to their various "S" curves. To evaluate this possible relationship, the approximate length of the dentinal tubules was measured by the above procedure, and statistical tests† were then carried out to determine whether the incidence of an inflammatory exudate was more closely correlated with the tubular R. D. or with the direct R. D. (Table II).

## HISTOLOGIC FINDINGS

Although severe inflammatory responses were not a prominent feature of this study, 25 of the 53 specimens revealed some degree of an inflammatory exudate.

*Van Huysen, G.: Personal communication.

†The authors are indebted to Jacob E. Lieberman of the Biometrics Branch of the Division of Research Services for his statistical analysis of the data.

TABLE II. SUMMARY OF THE STATISTICS OF THE DIRECT AND TUBULAR MEASUREMENTS FOR SPECIMENS WITH AND WITHOUT EXUDATE

| | DIRECT MEASUREMENTS | | | TUBULAR MEASUREMENTS | | |
|---|---|---|---|---|---|---|
| | SPECIMENS WITHOUT EXUDATE (0) | SPECIMENS WITH EXUDATE (+) | TOTAL | SPECIMENS WITHOUT EXUDATE (0) | SPECIMENS WITH EXUDATE (+) | TOTAL |
| Number of specimens | 26 | 25 | 51 | 26 | 25 | 51 |
| Mean (mm.) | 0.96 | 0.70 | 0.83 | 1.19 | 0.86 | 1.01 |
| Standard deviation | | | 0.48 | | | 0.60 |
| Coefficient of variation (%) | | | 58 | | | 59 |
| 99% confidence limits (mm.) | | | 0.65-1.00 | | | 0.80-1.23 |
| Analysis of variance | | | F = 4.06 | | | F = 5.39 |

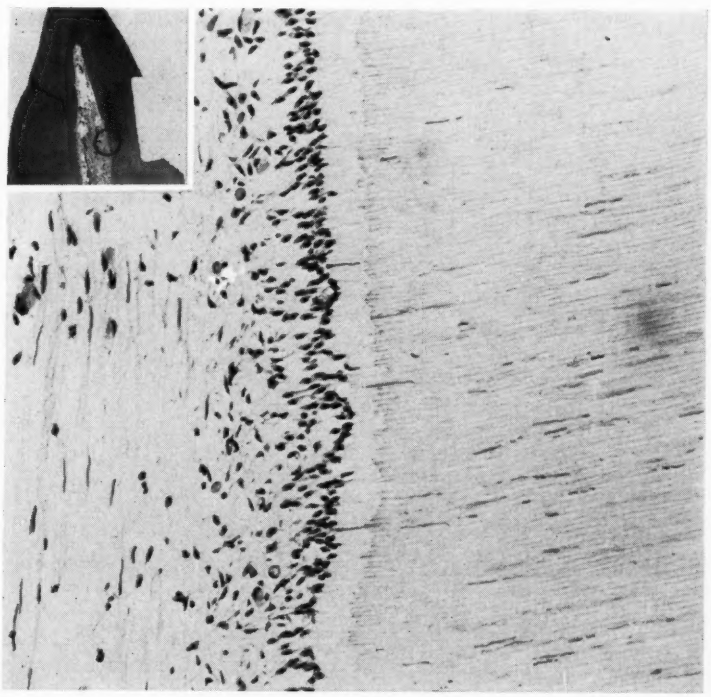

Fig. 1.—Two-day specimen (No. 3). The superficial layers lack infiltrating inflammatory cells. Some odontoblastic displacement is present. Architecture is generally intact. (×150; insert ×6.)

As indicated in Table I, 8 had less than one (+) degree, 11 had one (+) degree, 4 had two (++) degrees, and only 2 had three (+++) degrees. No intrapulpal abscesses were found, and all lesions were confined to the region underlying the pulpal ends of the cut tubules. All the specimens but those in the (+++) category revealed evidence of resolution of sufficient degree to warrant a favorable prognosis. The superficial layers, consisting of the odontoblastic layer, zone of Weil, and the cell rich layer, were generally free from any prominent infiltration of inflammatory cells (Fig. 1). The exudative cells, usually monocytes and lymphocytes, were mostly found deep in the pulpal tissues. Great numbers of neutrophils were seen (particularly in the 2-day specimens) in large, dilated, and congested capillaries deep in the pulp, but evidence of diapedesis was seldom noted.

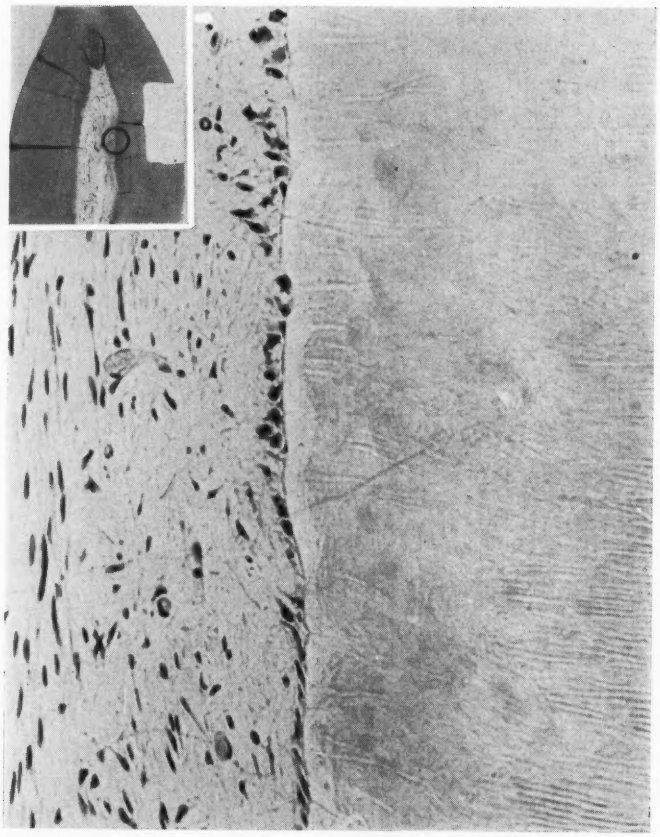

Fig. 2.—One hundred twenty-three day specimen (No. 48). Note single, disjointed odontoblastic cell layer in the presence of irregular secondary dentine. (×210; insert ×10.)

The statistical analysis substantiated the statement repeatedly made in the literature that the amount of remaining dentine beneath the cavity preparation plays an important role in the incidence of an inflammatory exudate. By the analysis of variance technique,[3] the F value was found to exceed 4.03 (tabulated

value for F with 1 and 49 degrees of freedom) in each category (direct and tubular measurements). Consequently, a statistically significant difference exists between the average dentine thickness of the specimens with an inflammatory exudate and the average dentine thickness of the specimens without an inflammatory exudate. However, there was no improvement in assessing the statistical significance when the actual tubular length was used instead of the thickness of remaining dentine (Table II).

Seventeen specimens revealed some degree of odontoblastic displacement. Nine of these had less than one (+) degree, 4 had one (+) degree, and 4 had two (++) degrees.

In 19 teeth, the only morphologic change was a slight decrease in height of the odontoblasts beneath the cut tubules. Sometimes minimal edematous and vascular changes were detectable in the adjacent tissues. The normal number of odontoblasts were present, but they appeared crowded together.

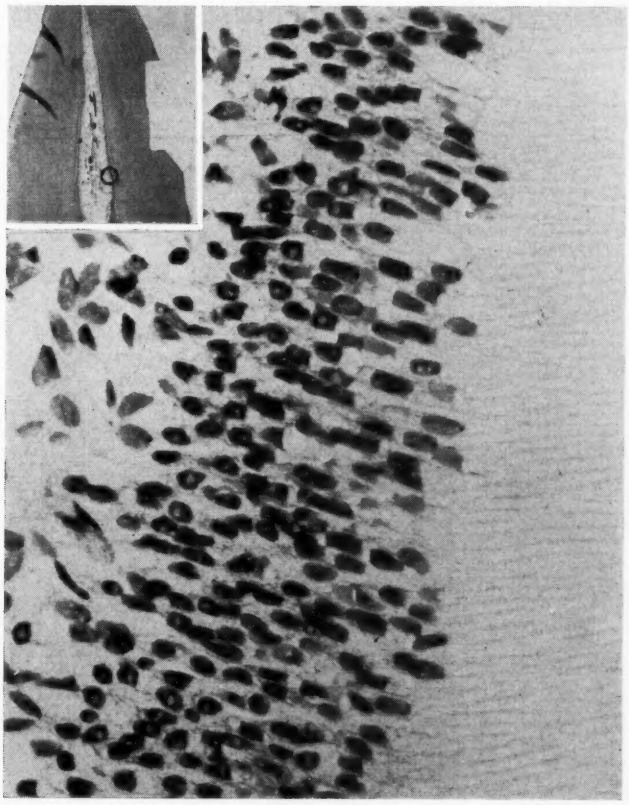

Fig. 3.—Sixteen-day specimen (No. 12). Note incidence of intranuclear vacuoles creating a moth-eaten appearance. (×400; insert ×10.)

Eleven specimens had a single layer of atrophic, flattened odontoblasts oriented with their long axes perpendicular to the dentinal tubules (Fig. 2). Seven of the eleven specimens revealed irregular secondary dentine or predentine.

An unusual finding was the occurrence in the odontoblasts beneath the cut tubules of one or more intranuclear vacuoles. These vacuoles first became noticeable at 5 days and gradually increased in number to give a generalized moth-eaten appearance to the odontoblastic layer by 16 days (Fig. 3). After 30 days, the incidence of vacuoles decreased.

Fig. 4.—Ninety-six day specimen (No. 36). The chromatin material (arrow) located at the opposite poles of the nucleus provides a safety-pin characteristic. (×1,400.)

Peculiar nuclei were occasionally seen in which the chromatin material was found at opposite poles, producing an oval, safety-pin characteristic (Fig. 4). This phenomenon could be found in specimens through the 123-day group. Occasionally, intranuclear vacuoles could be found in undifferentiated mesenchymal cell nuclei of the cell-rich zone deep to the involved odontoblastic layer.

Increased eosinophilic staining, primarily of the superficial tissues, was seen in 13 instances (Fig. 5). These tissues appeared morphologically normal, but the cells and intercellular spaces were uniformly altered in such a way as to result in increased eosinophilic staining. It was present at the ends of the shortest cut tubules if no exudate was present, but to one side of the shortest tubules, either above or below or both, if an exudate was present at that site. The intensity of

the eosinophilic staining was somewhat greater than in the amorphous material seen in the lumina of the adjacent lymphatics capillaries. Occasionally, the cut dentinal tubules showed intense eosinophilic staining. This reaction appeared as early as 5 days and was still found at 132 days, with no obvious change in character other than to appear possibly more pronounced at the later periods.

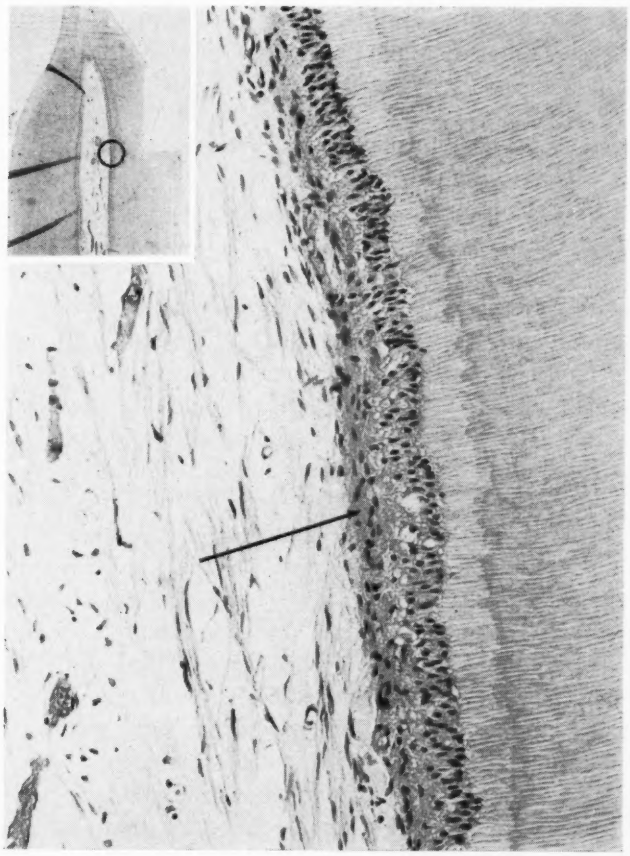

Fig. 5.—Ninety-six day specimen (No. 36). Insert demonstrates a dark line opposite lower corner of cavity preparation. Enlargement shows eosinophilic staining material (arrow) uniformly permeating the superficial layers of the pulp. (×140; insert ×10.)

## DISCUSSION

Although the incidence of an inflammatory exudate was roughly 50 per cent, the intensity of the exudate was 2 degrees or more in only 6 cases (12 per cent). The severest lesions encountered in the experiment were found in the (+++) specimens with an average direct R. D. measurement of 0.26 mm., which represents practically an exposure of the pulp. The scarcity of infiltrating leukocytes in the early phases of the experiment and the absence of intrapulpal abscesses and nodular formations of irregular secondary dentine in the later phases indicate a rather mild, traumatic injury to the pulp tissue by this operative procedure.

Although the statistical analysis showed that a significant correlation existed between the incidence of an inflammatory exudate and the quantity of remaining dentine, it should be pointed out that a weakness may exist in considering all the different morphologic types of teeth together. These same tests might be more meaningful if applied to larger groups of incisors, cuspids, premolars, and molars individually. However, so far as the actual structure of the dentine and its relation to the pulp tissues are concerned, little variation between the specimens would be expected regardless of the gross anatomic variations between the teeth.

It was previously shown[2,4] that, in the earlier time intervals, the intensity of the odontoblastic displacement was proportional to the degree of inflammatory response. In this study, displacement was not significant in amount because of the limited degree of inflammation created.

Vacuoles in the cytoplasm of odontoblasts are very common and thus far have been difficult to interpret. Seelig and Lefkowitz,[5] and Kramer and McLean,[6] described cytoplasmic vacuolations in odontoblasts both beneath and remote from cavity preparations. However, vacuoles within the odontoblastic nuclei were only occasionally seen. Römer,[7] described vesicular distention (blasenformize auftreibung) of the odontoblasts as an atrophic change. These vesicles resemble the intranuclear vacuoles found in our material. The characteristic was not specific for this operative technique but was more conspicuous in the 150,000 r.p.m. specimens than in those treated previously at lower speeds. The fact that the vacuoles occurred in specimens with a greater thickness of remaining dentine (1.4 mm.) than those in which an inflammatory exudate was noted (0.7 mm.), and that they increased and then decreased in number, suggests a subtle and reversible response to the cavity preparation. The safety-pin nuclei possibly resulted from the coalescence of several small vacuoles into single, large vacuoles, during the formation of which the chromatin material may have been pushed aside. Baird and Fisher,[8] were able to produce intranuclear vacuoles in the hepatic cells of rats by intraportal injections of hypotonic solutions of N/2 NaCl. Their findings suggested that the alteration possibly resulted from a disturbance of osmotic equilibrium at the nuclear membrane. The absence of lipid, inconsistent demonstration of glycogen, and no apparent increase in protein offered support to the contention that the swelling and optical clearness of the nuclei may well have resulted from an increased water content. The process of vacuolization appeared to be reversible in the human being. Altered nuclei were observed in sections obtained by needle biopsy during life, whereas necropsy sections of liver from the same patient failed to reveal this change. To draw any definite conclusions about odontoblastic intranuclear vacuoles from the above study is purely conjectural. However, it is conceivable that the trauma of cavity preparation could disturb the osmotic equilibrium at the odontoblastic nuclear membrane and result in an increased uptake of fluid leading to vacuolization.

The significance of the eosinophilic staining material was not elucidated in this study. Seelig and Lefkowitz[5] previously considered the eosinophilic substance to represent a protein diffusion into the ground substance, arising from the escape of blood plasma through capillary walls irritated by the eugenol in zinc-oxide and eugenol fillings and by autopolymerizing acrylic resins. It appears peculiar that the characteristic was missing in those specimens in which the response was severe

enough that an exudate was produced. Since it occasionally occurred peripherally to an exudate, eosinophilic characteristic may also signify a milder response.

## SUMMARY AND CONCLUSIONS

1. An evaluation of the pulpal response was made in 53 sound human teeth in which cervical (Class V) preparations were cut with an inverted cone tungsten carbide bur rotating at 150,000 r.p.m. A belt-driven contra-angle type handpiece equipped with a rubber chuck was used. All teeth were filled with zinc oxide and eugenol cement and extracted at intervals ranging from less than 1 hour to 132 days after cavity preparation.

2. This operative procedure appeared to produce a *mild,* traumatic injury to the pulpal tissues, as evidenced by the scarcity of infiltrating leukocytes in the early phases of the experiment and the absence of intrapulpal abscesses and nodular formations of secondary dentine in the later phases.

3. No advantage was gained in the estimation of the pulpal reaction by relating the histologic findings to the actual length of the tubules from the floor of the cavity preparation to the underlying pulp instead of to the directly measured thickness of the remaining dentine.

4. Observations concerning the phenomena of intranuclear vacuolization of odontoblasts and increased eosinophilic staining are presented.

Grateful acknowledgement is made to Alexander M. Schwollman for preparing the microscopic sections and to Robert R. Padgett for preparing the photomicrographs.

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Bethesda 14, Md.

# A CRITICAL EVALUATION OF ULTRASONICS IN DENTISTRY

EDMUND V. STREET, D.D.S.*
*University of California, School of Dentistry,*
*San Francisco, Calif.*

DURING THE PAST FORTY years, many new ideas have been suggested to improve our techniques of performing certain operations. Dentists, in general, are receptive to these new concepts if they can be performed readily, are not too costly, and conserve time, which usually means increased income. Among the more recent innovations is the Cavitron. This ultrasonic instrument is capable of cutting enamel and dentine in human teeth so that cavities can be prepared which are comparable to those made by the conventional dental handpieces and burs.

An enthusiastic reaction to this new method of tooth preparation has been expressed by individuals in the dental profession.[1,2,5] Favorable patient reaction has also been mentioned,[1-5] and the histopathologic evaluation of pulpal response has been studied and revealed.[6-8,15] These indicate that the vitality of a dental pulp in a permanent tooth is not jeopardized any more by this procedure than with moderately high speed (up to 20,000 r.p.m.) techniques.

A pilot study was performed by the author upon the incisors and canine teeth of a 1½-year-old dog. Four cavities were prepared with a 2 mm. cylindrical diamond instrument rotated at 18,000 r.p.m. under a coolant of running water, and seven cavities were prepared with the same size Cavitip in the handpiece of the Cavitron. These preparations were made at various times so that there would be intervals of 3 hours, 2 days, and 25 days between the time of extraction of the teeth and the time of preparing the cavities. Five of the anterior teeth were used as controls.† Frisbie‡ examined all of the sections without any knowledge of the method of preparing the cavities, and his report indicated that no unusual pulpal disturbances were noted.

One must not be lulled into a false sense of security by these findings because others have warned that deleterious reactions can occur. Hansen and Nielsen[10] found that the pulps in the teeth of guinea pigs are severely affected, and Crawford[11] warns that "ultrasonic vibrations in children's teeth would seem, at present, to be contraindicated." Jensen and Sausen,[12] in their experiments employing pressures of 4 or 5 pounds, produced severe pulp reactions and necrosis.

This article will reveal some favorable, as well as unfavorable, reactions as a result of 2 years of my experience with the Cavitron. All of the work with this machine and the experiments performed were completed in the laboratory.

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*Professor of Operative Dentistry.

†The teeth were fixed, decalcified, sectioned, stained, and mounted in the Department of Oral Histology.

‡H. E. Frisbie: Personal communication.

THE UNIT

The Cavitron dental unit Model 210 (Fig. 1) is housed in a cabinet 37 inches high, 20½ inches wide, and 16 inches deep. The cabinet is mounted on four swivel-type rubber casters for mobility. It occupies a space approximating that

Fig. 1.—The Cavitron dental unit.

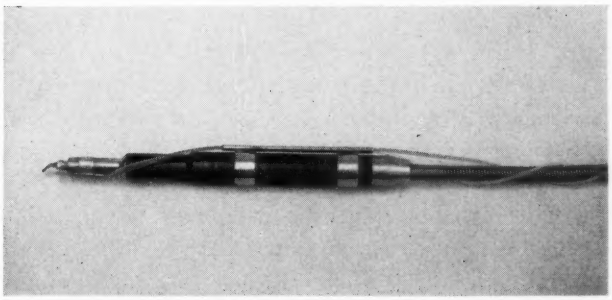

Fig. 2.—The Cavitron handpiece.

required for a three-drawer filing cabinet. In addition to the line for the electric current, two hose lines are connected to the dental unit. One of these carries the supply of water, and the other carries the compressed air.

The handpiece (Fig. 2) is only slightly larger than the conventional dental handpiece and may be held in a similar manner. Its weight is about the same, but it

lacks balance in the finger grip which is probably because of the additional weight of the suspended cable. This cable carries the exciting current to the handpiece, the clear water line, and the abrasive slurry (aluminum oxide and water). This cable might well be suspended from an upright rod on the side of the machine which would minimize the finger fatigue.

A foot control, quite similar to that employed with the rotary electric engine, is simple to operate but is too light in weight. It tends to "move away" from the foot.

## CUTTING INSTRUMENTS

At the present time, nineteen Cavitips are available for cutting cavities (Fig. 3). Each tip has a specific shape and size and will produce a cut in the tooth substance similar to its form as long as a direct thrust is employed. Some of the tips can be directed to widen or lengthen a cut merely by exerting a lateral movement.

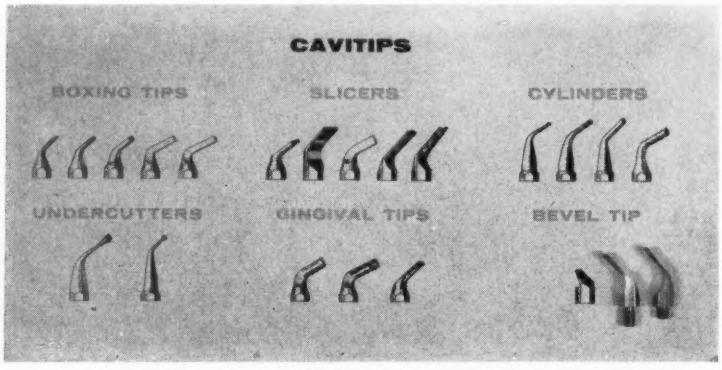


**Fig. 3.**—The Cavitips. A comparison of the increased length of the threaded section on the newer tips is shown at the lower right.

Line angles of a cavity are sharp provided the edges of the Cavitip are not rounded. As the instrument is in function, an abrasive slurry (particles of aluminum oxide) is carried to the tip by means of a stream of water. It is this slurry that actually cuts the tooth. However, this abrasive action is transmitted also to the metal tip and, in a relatively short time, the initial sharp edges of the instrument are rounded, and its cutting action is lessened. It takes only a half minute or so to re-establish the flat cutting end with a mounted Carborundum stone, but there is a limit to the resurfacing as the tip can only be shortened a certain amount before it must be discarded.

A quicker method of reshaping the tips is to press the button on the foot control to shut off the flow of water, then place the dry, vibrating tip against a fine Carborundum stone so that the cutting edge of the tool is perpendicular to the stone. After a few seconds, the tool will again have sharp edges, and it is this type of tip that will produce the ideal cavity preparation with sharp line angles.

These tips are attached to the handpiece by means of a threaded section and must be fixed firmly into position by means of a special wrench. The procedure of changing tips is much more time-consuming than that of changing latch type burs in the ordinary contra-angle handpiece. The time required ranges from 30 to 40 seconds, including the "alcohol dip" to cleanse the threads of the nickel tube.

## MANIPULATION

Once the unit has been installed with all connections intact and the proper slurry consistency determined, the dentist is ready to attach the desired cutting tool.

The instrument is tuned by regulating the tuning dial so the maximum efficiency of the machine will be assured. This may be accomplished by three methods: First, by observing the fine spray of water off the tip; second, by noting the "oily" or "velvety" sensation as the dry shank of the Cavitip is stroked against the finger; and third, by observing the sudden backward shift of the tuning meter needle as the tuning knob is advanced. One must be sure that the output knob has been properly set. Not all cutting tips operate satisfactorily at the same output.

During the first year of experimentation with the Cavitron, one of the most annoying problems was the too frequent loosening of the Cavitip. It was necessary to stop the operation and reset the tip with the special wrench. This problem was eliminated by new tips having a threaded section just about twice as long as the first ones. Great care is necessary to keep the threads on the Cavitips and those within the nickel rod perfectly clean. The suggested method is to dip the exposed threads in a container of alcohol and turn the instrument on at the maximum vibration tuning range for a few seconds. Then the tool is withdrawn, and the fluid is blown out by means of compressed air. The handpiece is then ready to receive the new Cavitip.

## OPERATING PRESSURES

The printed instruction to apply very light pressure of the Cavitip against the tooth is inaccurate. One dentist may construe this as barely touching the object, while another may exert a pressure of one pound and believe that to be a light load. Experience with burs, stones, and diamonds (where tests were made with a pressure gauge) dictates that a light load must be applied to cut with the Cavitron. When a load of four ounces or less is applied to a tungsten carbide bur while rotating against tooth enamel at speeds up to 40,000 r.p.m., very little tooth substance is removed, whereas, a 2-pound load will result in maximum cutting action.

Under test conditions, the cutting action of the Cavitron was found to abrade the enamel of a tooth under varying loads, but the cutting rate was much more effective at a load of 2 ounces.

If the handpiece is suspended at a 45-degree angle from the flexible cable immediately adjacent to the back end of the instrument, the load delivered through the Cavitip to the object being cut will approximate 2 ounces. When a load of more than 4 ounces is applied, the instrument produces a "whining" sound, and very little, if any, actual cutting is performed.

The dentist must be certain that no interference with the flow of the abrasive slurry occurs while the handpiece is in operation. Should the nozzle, from which the slurry is propelled, be too far from the Cavitip, a fingertip or a portion of the tooth might interrupt the flow and immediately suspend the cutting action.

### CUTTING IN ENAMEL

The tools will cut most effectively on those parts of the tooth having the greatest thickness of enamel. When the enamel has been penetrated, the rate of tooth removal is decreased.

The effectiveness of the Cavitron in removing enamel, dentine, carious enamel, and carious dentine was investigated. The tests were made upon moist extracted human teeth. The instrument was held in contact with the hard tooth substance for one minute in each test, and the applied load was limited to 2 ounces. This proved to be the optimal load as based upon earlier experiments. Each tooth was rinsed in distilled water, wiped dry, and the remaining moisture blown off both before and after each test.

The amount of tooth substance removed was evaluated by weighing the specimen on a balance graduated in milligrams. From five to fifteen cuts were made with each kind of tip, and the figures in Table I represent the average of at least five cuts, listed in the order of effectiveness.

TABLE I. THE WEIGHT OF TOOTH SUBSTANCE REMOVED IN ONE MINUTE*

| | |
|---|---|
| Cylindrical tips | 22 mg. |
| Gingival tips | 31 mg. |
| Boxing tips | 33 mg. |
| Slicer tips | 35 mg. |

*Two ounces of pressure.

These figures compare favorably with the cutting rate of the rotational instruments, such as tungsten carbide burs and cylindrical diamond instruments, at speeds up to 40,000 r.p.m. at loads of 16 ounces. However, these instruments with loads of 24 and 32 ounces revolving at 40,000 r.p.m. will remove 3 to 6 times as much enamel. On the basis of more recent findings, a much greater amount of enamel can be cut when even higher speeds are employed. Preliminary figures indicate that well over 200 mg. per minute of enamel may be removed at rotational speeds of 160,000 r.p.m. with no greater load than 4 ounces.

### CUTTING IN DENTINE

The cutting action of the ultrasonic machine in dentine was one-half to two-thirds the rate of that in enamel. When compared to the cutting rate of ordinary carbon steel burs or tungsten carbides, the rotating types of instruments at speeds up to 24,000 r.p.m. surpassed the ultrasonic method by upward of twenty-five times.

The contention that walls of cavities prepared by the Cavitron will actually be more smooth than those cut by rotary instruments[2,14] is not supported by this

study. The cut surfaces of enamel appear to be fairly rough when viewed microscopically (Fig. 4). The irregularities vary from small nicks to very large gouged areas. By comparison, the specimen has as many indentations, and the surface appears to be at least as rough as the enamel cut with a sharp Wedelstaedt chisel (Fig. 5). The latter instrument did not produce the smooth enamel surface that could be obtained with rotating burs or stones as previously reported by the author.[13] Differences in the smoothness of walls, the sharpness of angles, and the flatness of floors of cavities, when prepared with rotary instruments and the ultrasonic device, are portrayed vividly by Mitchell and Jensen.[15]

Fig. 4.

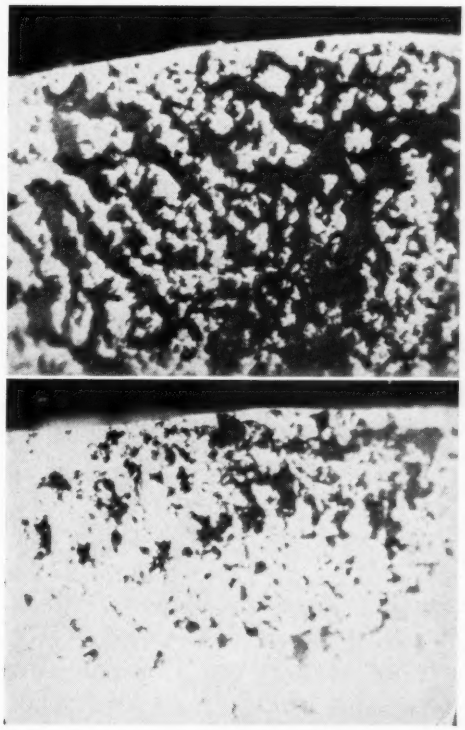

Fig. 5.

Fig. 4.—Gouged areas in enamel are produced by the ultrasonic device (× 37).
Fig. 5.—Numerous nicks are produced in enamel with a sharp Wedelstaedt chisel (× 37).

## CUTTING IN CARIOUS DENTINE

Excavation of carious dentine was probably the greatest disappointment in this whole project. The rate of removal of caries by means of the ultrasonic cutting instruments was never greater than 3 mg. per minute. The special spoon excavator tips (similar in size and shape to the conventional hand instruments) failed to compare satisfactorily with the removal of decayed dentine by the established method.

### CUTTING IN EXISTING RESTORATIONS

One of the most annoying operations in a dental practice is the removal of old metallic restorations. Prior to the introduction of the carbide burs, amalgams, gold foils, and inlays, metallic restorations generally had to be cut tediously with the carbon steel bur and removed in pieces. The tungsten carbide bur with its harder steel and greater "bite" cuts readily through amalgam, gold foil, silicate, plastic, and cement. The cast gold inlay still is the most resistant of all restorations, but the carbide bur will penetrate this metal to a much greater degree than will the carbon steel bur. The ultrasonic instrument will cut amalgam and silicate fairly well, but it leaves only a faint mark on inlays and plastic fillings. Removal of gold foil restorations is a very tedious procedure, and cements, particularly zinc oxide and eugenol, are cut only with difficulty.

### COOLANTS

With high-speed cutting methods and the ultra high-speed techniques, water coolants are essential. These may be in the form of air and water to produce a spray, or a stream of running water. In either instance, efficient removal of the liquid can usually be accomplished by means of the saliva ejector. When using the ultrasonic technique, the stream of water (combined with the aluminum oxide) can be removed through the saliva ejector, but the metallic abrasive quickly settles out, and frequent washing or flushing operations are required to clear the cut areas of the cavity to obtain satisfactory vision.[1,9] Frequent flushing is desirable for removing the accumulation of slurry from the floor of the patient's mouth. Postle and Lefkowitz[14] state, "The saliva ejector alone is inadequate."

### FILLING CONDENSATION

A suggestion[1,16] has been offered that amalgam and gold foil restorations might be condensed into a cavity with the Cavitron. To determine the value of this method for amalgam, forty-three crushing strength tests were made in accordance with the recommendations of the Bureau of Standards. The average for these was 36,000 pounds per square inch at the end of 24 hours. For comparative purposes, 31 tests were completed in which the Hollenback pneumatic mallet was employed. The average for this method was 46,000 pounds per square inch. In a third series of 23 tests, the condensation was accomplished by hand, and the average crushing strength was 44,000 pounds per square inch.

The low crushing strength of the amalgams condensed by this machine will not make it a desirable method if a strong restoration is the objective.

Flow tests were performed in the accepted manner and readings taken at the end of 24 hours. Six specimens condensed with the Cavitron gave an average flow of 6.93 per cent, while three made with the pneumatic mallet averaged 1.54 per cent. The nine hand-condensed molds had an average of 2.18 per cent. The maximum flow allowed under specification No. 4 of the American Dental Association for acceptance of a silver alloy is 4 per cent. The figure of 6.93 per cent would indicate that the ultrasonic method of amalgam condensation is inadvisable.

Four specimens of gold foil were condensed in a split steel mold, each of which measured 10 mm. long, 1.5 mm. wide, and 1.5 mm. deep. Pellets of pure gold, ⅛ and ¼ grain, were condensed with a serrated point having a diameter of 1.5 mm.

The results of the first experiments proved negative, because the condenser point caused both annealed and unannealed gold foil to flake completely out of the mold. Readjustment of the output and tuning dials reduced this action but did not stop it completely. According to Mitchell,* the flaking was caused by "work-hardening" of the gold. It is also possible that too much heat was transmitted to the gold. This would scorch the foil, shriveling the edges, and generally rendering it harsh and unworkable.

Brinnell hardness tests were made in 3 portions of each gold foil specimen. These tests were made with a 10 Kg. weight on a 1/16 inch ball for 30 seconds. The best filling revealed a Brinnell hardness number of 10. All the others ranged below this down to 2. This method failed to compare favorably with the accepted condensation techniques wherein hardness tests averaging 64 were reported by Rule.[17] Lack of satisfactory stepping and the relatively large condenser point with deep serrations prevented proper cohesion of the gold. A light load of very short duration was necessary to obtain any degree of cohesion. This is contrary to the fundamental principles of proper condensation of gold foil. The pitted condition of the specimen left much to be desired insofar as surface appearance was concerned.

It is difficult to imagine using the Cavitron to produce a smooth surface on a restoration such as an amalgam, silicate, or gold, but to evaluate its effectiveness, attempts were made to accomplish this surfacing. They proved to be most unsatisfactory. To prepare restorations for polishing, one must resort to the use of the conventional rotary instruments. For a complete, conscientious service to patients, proper finishing and polishing of restorations are necessary.

### USE IN PERIODONTICS

If one were to employ this instrument for the removal of calculus and stain from the exposed surfaces of the teeth, the ensuing polishing steps would require the conventional rotary type handpiece. The curettes or scalers and their handles, that dentists have been using for many years, are light and well balanced. By comparison, in my hand the Cavitron handpiece is awkward. When a curette or scaler point is attached, it is poorly balanced and cumbersome because of its bulkiness and shape. This might be remedied partially by suspending the handpiece cable from a staff on the cabinet similar to the suspension of the conventional handpiece from the balanced cord arm.

### TIME CONSUMPTION

The actual time consumed in cutting cavities by the ultrasonic method did not seem to be any less than by the rotary method. When one has had the experience of removing tooth structure with the ultra high-speed rotary equipment at revolutions above 150,000 per minute, it is quite apparent that we have been operat-

*J. V. Mitchell: Personal communication.

ing in the "horse and buggy days." On the other hand, both the ultrasonic and turbine rotational machines are strictly adjuncts to our present armamentarium. Postle and Lefkowitz[14] point out the need to supplement most operations with excavators and chisels, and I wish to emphasize the fact that a number of operations still require slow rotating instruments.

## DISCUSSION

Maintenance of the equipment in a satisfactory working condition was no simple task at the beginning. Typical of so many mechanical innovations, certain "bugs" appeared in the new equipment. During the early experiments, the handpiece overheated and, on a few occasions, it was too warm for comfort in the hand. When this occurs, an immediate check of the water flow should be made. According to the "Cavitron Manual," this flow should be at the rate of approximately one pint per minute. The first handpiece used in this work had a flow of only one ounce per minute, even though the water pressure gauge registered 16 pounds at all times. The third handpiece had a flow of two ounces and did not overheat quite as much. The replacement of the handpiece cable receptacle was recommended. This resulted in the normal flow of cooling water, and the handpiece did not become even warm.

One of the most disagreeable jobs in the maintenance of this machine is the need for removing and cleaning the mixing chamber twice monthly. After performing this task a few times, it would be safe to assume that the dentist or his assistant would neglect this procedure thereafter. It is not likely that the average assistant is capable of performing this task alone. Disassembling the spring hooks, Cavident, water lines, and the pump assembly, and then removing and cleaning the parts is no easy matter.

To prevent the possibility of clogging in the plastic Cavident line, the abrasive material should be flushed out at the end of each day. This can be done by removing both lines at the side of the cabinet and setting the Cavident brass hose tip into the rinsing water line and running clear water through the line for a few seconds.

The threads in the nickel rod of the handpiece may become stripped or worn. When this occurs, the cutting tip loosens, and its operative effectiveness is restricted. To minimize this wear, it is essential to clean the threads in the rod and on the Cavitip whenever the tip is removed. Regardless, these threads do wear, and replacement is necessary.

## SUMMARY

Some dentists who have employed the ultrasonic method of preparing cavities and patients who have experienced its use express favorable comment. Pulps of vital permanent teeth appear to be unaffected, but operations on children's teeth should not be attempted until future research indicates no ill effects.

The original cost of the unit, its size, and the fact that it is strictly an adjunct to the present armamentarium of the dentist will probably be a deterrent to its

acceptance. Cleaning and attaching the tips, tuning the machine, and applying the correct load while operating are discouraging aspects to the beginner.

The ultrasonic method of cutting carious or sound enamel, carious or sound dentine, and certain types of restorative materials does not approach the effectiveness that can be demonstrated with the ultra high-speed rotational instruments.

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University of California Medical Center
School of Dentistry
San Francisco 22, Calif.

# ENDODONTICS

PAUL K. HILL, D.D.S.
*Pasadena, Calif.*

PRESENT-DAY ENDODONTICS IS decidedly effective and is an excellent example of the application in dentistry of information gained from allied biologic fields. It is a most satisfying branch of dentistry. It is gratifying to save a useful organ for years of service for an appreciative patient. Our patients, realizing that this work is available to them, are now demanding, with no fear of menace to their general health, that their teeth be saved. The concurrent development of improved methods, material, instruments, and concepts has provided simplified and effective treatment procedures.

The philosophy of endodontics based on the research of Fish[1] and MacLean has become the foundation of thinking in the treatment of all pulp-involved teeth. Briefly, this research proved that the bacteria in the pulp-involved tooth were found only in the pulp canal and at the immediate apex of the root. The area of rarefaction or bone destruction shown in the roentgenogram was the result of the lysing action of proteolytic enzymes produced by the decomposition of proteins in the pulp tissue itself. Accepting this theory, the endodontist can proceed confidently to débride, sterilize, and seal the canal with modern methods at hand. Armed with antibiotics, singly or in combination, electromedication, and time-tested germicides, the endodontist may treat root canals more successfully than ever before.

Root canal treatment still remains one of the most widely discussed problems in dentistry. As confidence in treatment has increased and many successful results have been viewed, the psychologic barrier against the practice of saving pulpless teeth is rapidly breaking down.

## PULP CAPPING

Despite our efforts to control it, dental caries still remains the most prevalent of dental diseases, and along with its progress, pulp involvement and pulp disease occur. The nearly exposed pulp through dental caries, or the newly exposed pulp through caries or operative procedures, need not be extirpated.

The response of the vital pulp to irritation is the laying down of secondary dentine. In teeth where the coronal portion of the pulp may be suspected of being infected, partial pulpectomy has been advocated and practiced successfully for many years. Pure calcium hydroxide is the material of choice to be placed over the operated pulp stump. The necrosis of the superficial layer of the pulp, brought on by the irritating action of the calcium hydroxide, is followed by a deposition of new

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dentine with retained vitality of the pulp stump. These operations have been considered most successful only in young, large pulps.

Massler* has shown that the extreme partial pulpectomy was not always necessary, nor was the capping of pulps in young, large pulps the only one to succeed. He has demonstrated dentine bridging at the point of pulp exposures of adults as well as of those of young persons.

Berman and Massler[2] have reported the results of experimental pulpotomies on rat molars. Pulp amputations were done on 120 upper first molars of 60 male hooded rats aged 50 to 125 days. Some of the wounds were covered with calcium hydroxide, others with zinc oxide and eugenol, and sealed with amalgam. The animals were sacrificed at intervals of 7, 14, 21, and 28 days. The lesions of the exposed pulp tissue under large or small exposures exhibited the same reaction to both medicaments. At both 7 and 14 days, the amputated pulp showed degeneration and necrosis, the reaction being slightly more severe under zinc oxide and eugenol. However, at 21 days a dentine bridge was seen under both medicaments, and it was assumed that the necrotic zone was related to and essential for formation of new odontoblasts and the forming of the dentine bridge. By 21 to 28 days the formation of the dentine bridge under both calcium hydroxide and zinc oxide and eugenol was fundamentally the same.

The conclusion was drawn that a calcium compound is not essential to pulp healing and the formation of a dentine bridge. Gentle handling of the pulp tissue and a definite seal against contaminating oral fluids was deemed to be the most important precaution for pulp healing. The healthy, vital pulp seems to respond similarly under various medicaments.

To test the pulpal response to pulpotomy procedures, James, Englander, and Massler[3] reported results of pulp capping with combinations of calcium hydroxide and antibiotics and with antibiotics alone. Their evaluations were based on severity of inflammation, incidence of bridging, or internal resorption. Amputated pulps covered with calcium compounds showed a significantly greater incidence of bridging, a lesser incidence of internal resorption, and lesser severe inflammation than those covered with antibiotics. Of the four antibiotics used, amputated pulps covered with the polyantibiotic mixture (P.B.S.C.) showed the highest incidence of bridging. The group covered with penicillin showed the highest incidence of internal resorption. When calcium compounds were combined with an antibiotic, the pulpal response resembled that of the antibiotic more closely than that of the calcium compounds. There appeared to be a direct relationship between the severity of inflammation and the incidence of internal resorption and an inverse relationship between the degree of inflammation and the incidence of bridging.

## ROOT CANAL TREATMENT

Contemporary authors are stressing the débridement or cleansing of the canal. Sterilization, while still considered important, is the least important. Sterilization of an improperly operated canal cannot be successfully accomplished.

*Massler, M.: Personal communication, Southern California State Convention, 1936.

The instruments for operating the canal have changed little through the years. Files and reamers seem to be the instruments of choice. Recently, Hedstrom files have appeared from Europe and were introduced by Nygaard Ostby of Oslo, Norway. The Hedstrom file has a different design with a circular blade in contrast with the spiral file commonly used. It is particularly efficient in extirpating pulp tissue since it tends to chop the tissue into bits so that it may be flushed out of the canal. These circular blades, being very sharp, also cut the walls of the canal most easily and tend to decrease operating time. Since they are available in sizes of from numbers one to ten, the larger sizes are particularly valuable in operating larger canals.

Flushing agents remain the same. These are chlorinated soda and hydrogen peroxide. Clark* has reported the use of Clorpactin, a hypochlorous acid, as a flushing, cleansing, and sterilizing agent. The activity of clorpactin is based on its active chlorine content, acting in conjunction with the powerful wetting and penetrating properties of the base, and stabilized and controlled by specially developed buffers. The bactericidal potency of Clorpactin is very similar to that of elemental chlorine, yet it does not have chlorine's toxicity or destructive effects upon tissue cells.

Another most useful aid in the operating procedure is that of aspiration. I have employed an aspirator fashioned from a Beck and Dickinson attachment, soldered on a metal tube, which will fit into a saliva ejector or aspirator tube. This attachment will take any gauge B and D needle required for aspiration.

Wolfsohn† has devised an aspirator attachment which uses a rubber cup as the aspirating tip. This is called a Spirojector.

Since irrigating solutions used are irritants to the periodontal membrane, aspiration is valuable in removing these substances from the canal. Aspiration is also of great value in removing pus, debris, and ointment dressings.

The most interesting and dramatic addition to the endodontic armamentarium is a new adjunct for widening small, restricted canals. Since chlorinated soda and peroxide have no action on the canal walls, inorganic acids in various dilutions have been used in conjunction with files and reamers. These acids have not been entirely satisfactory because of tissue irritation when pumped through the apex of the root and because of insoluble chemical compounds formed which were difficult to remove. They also corrode instruments.

This new substance, introduced in this country by Ostby,[4] is a chelating substance known as ethylenediamine tetra-acetic acetate (E.D.T.A.). A sterilizing agent Cetvalon is combined with it and marketed under the name of E.D.T.A.C. E.D.T.A. was first used for the demineralization of bone specimens for histologic study. It was found that it would also dissolve powdered dentine. A 15 per cent solution (pH of 7.5) has been found to be most satisfactory for softening the walls of root canals in from 3 to 5 minutes.

The solution is neither bacteriocidal nor bacteriostatic, but it inhibits the growth of, and will eventually destroy, bacteria by the process of starvation. The metallic ions in the culture media which are necessary for growth are chelated and thus rendered unassimilable by the microorganisms.

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*Clark, E. Bruce: Personal communication.
†Wolfsohn, Bertram I.: Personal communication.

E.D.T.A. is entirely neutral to the gingival mucous membrane as well as to the pulp and periapical tissues. In teeth with narrow or obstructed canals, it may be sealed in the canal. Since its action is self-limiting, the surface of the canal will be demineralized, and this may be removed easily at the next sitting. It also has no corrosive or any other deleterious effect upon metal instruments.

## DRUGS AND STERILIZING AGENTS

The action of any drug in the treatment of a root canal is secondary in importance to the thorough instrumental removal of the pulp material and the sides of the walls of the canal. The proper enlargement of the canal requires skill, digital dexterity, and patience. This débridement opens the way for the successful application of any drug.

Rational medication begins with thorough chemomechanical preparation of the canal. Auerbach[5] has demonstrated that by careful mechanical cleansing and irrigation of the canal alone, without use of further medication, 78 per cent of the infected teeth thus treated yielded growth-free cultures. Stewart,[6] in a similar study, found that 76 per cent of infected teeth thus treated were free of microbial growth. The percentage was calculated after two consecutive negative cultures.

Perhaps the one thing which has bolstered the faith and confidence in root canal therapy more than anything else was the discovery of antibiotics. These drugs used singly and in combination, both topically and internally, in acute and infected teeth, have given astonishing results.

Since a prime requisite of any medicament used to sterilize a root canal is that of being nonirritating to the periapical tissues, combinations of antibiotics have become very popular. The polyantibiotic suspension or ointment of Grossman,* consisting of penicillin, bacitracin, streptomycin, and sodium caprylate has been most publicized. Stewart[6] suggests a similar mixture substituting chloramphenicol for streptomycin and another modification with penicillin, chloramphenicol, chlorcyclizene (an antihistamine), and lidocaine ointment. This, he claims, not only eliminates the microorganisms but also reduces the postoperative discomfort, no doubt due to the antihistaminic action.

Blitzer[7] reports a mixture of terramycin, antihistamine cortrie, and terracyn, T.A.C.T., plus hyaluronidase to be more successful in the treatment of acutely infected teeth where penicillin mixtures had failed previously. Hyaluronidase is an enzyme which disseminates the medication through fistulous tracts and surrounding tissues.

In acute cases with temperature and swelling, administration of terramycin, 250 mg. every 4 hours around the clock usually brings quick relief. If this fails, another 24-hour dosage of ilotycin, 250 mg. at the same intervals, will usually allay the infection.

Criticism of the polyantibiotic mixtures has been offered, since they are believed to be only bacteriostatic instead of bacteriocidal. Also, it is deemed difficult to get a true culture from a canal containing antibiotic mixtures.

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*Grossman, L. T.: Personal communication.

Compounds containing chlorine are the most widely used drugs in root canal treatment. Camphorated paramonochlorphenol is the drug of choice of many dentists. It is nonirritating and highly germicidal.

Wolfsohn* has used medicated ointments in root canals with the elimination of paper points. The theory is that the ointment can be placed and forced through the entire length of the canal making its medicament most beneficial. He has found Formocresol (a previously irritating drug) to be nonirritating when made into an ointment with aquaphor. It still retains its valuable germicidal properties. Camphorated paramonochlorphenol seems to be rendered less active when mixed into an ointment.

Sommer, Ostrander, and Crowley[8] have suggested a combination of camphorated paramonochlorphenol with penicillin. Their results have been excellent.

The advantage of any of these polyantibiotic suspensions or medicated ointments is that they may be applied to the canal from a Luer-lok syringe through a 23-gauge needle, assuring their contact throughout the length of the canal. Ostby† suggests a paste made of sulfathiazole and thiosulfil packed into the canals of acutely infected teeth following aspiration of pus and exudate. This is most effective.

Iodine and chlorinated soda are used extensively in electromedication which is still a popular and effective method of sterilization. This method is especially indicated where epithelial tissue is suspected, as in cystic formations. The electrical current in conjunction with iodine will break down this tissue.

## ROOT CANAL FILLING

Gutta-percha cones and silver cones are the materials used. Due to their rigidity in the smaller sizes, the silver cone is the choice for use in molars and small canals.

These filling materials are inaccurate in size and shape compared with endodontic instruments. This makes the filling operation difficult. One manufacturer is attempting to standardize filling material size and instrument size, although the ultimate goal has not been reached. The shape of filling materials has been changed at least to approximate more nearly the taper of the preparing instrument.

The method of filling is to cement the cone of gutta-percha or silver to place with a nonirritating zinc oxide eugenol cement.

Ingle[9] suggests that the canal be prepared as a tapering canal to a minimal opening and that the canal be obturated or sealed at a point 0.5 mm. from the apex to achieve the ideally filled root canal.

## SURGERY

The attempt to utilize biologic principles and to invoke the aid of living cells to repair damaged tissue is not new in dentistry. It simply follows current trends in endodontics. A decade ago, periapical rarefactions were generally treated by surgical removal immediately following root canal therapy. Today, the trend is

*Wolfsohn, Bertram I.: Personal communication.
†Ostby, Nygaard B.: Personal communication.

toward avoiding apicoectomy, and depending upon the ability of periapical connective tissue to heal itself, once the toxic agents have been removed and the canal has been sealed against reinfection. Less caustic drugs and milder sterilizing agents are preferred. Aseptic procedures and respect for living tissue are the order, based on the recognition that living tissue can combat infection and does heal.

Grossman* states that only 3 to 5 per cent of cases require surgery. It is recognized that where large cystic and granulomatous areas exist, surgery hastens the healing process.

The greatly neglected fields of diagnosis, control of pain, and selection of cases is all important but could not be included in this report.

That interest in endodontics is on the upswing is evidenced by the increase of teaching of the subject, both on the undergraduate and postgraduate levels. In a survey of 37 dental schools conducted by Sommer[10] in 1954, the fact was established that 32 of the schools included endodontics in their curriculum. This is a marked contrast with the trend of not so many years ago when endodontics was shunned by all but a very few schools and was considered uninteresting, unnecessary, time-consuming, and impractical.

That too much emphasis was placed on the treatment of single-rooted teeth was brought out in the survey. Thirty schools required students to treat both anterior teeth and bicuspids, but only 22 schools required students to treat molars. These findings caused Sommer to close his report[10] with this comment: "The relatively low minimum requirements and the emphasis on anterior teeth are a result in my opinion that at least under our curriculum it is better to teach fundamentals in a way that will more nearly be used in general practice. Students [as well as dentists] should see successful cases and experience pleasure in treatment until the old stigma of 'tedious, time-consuming treatment of questionable value is overcome.' "

## CONCLUSION

It can be seen that endodontics is an established, recognized field in dental practice. The preservation of pulp-involved teeth through biomechanical procedures has broadened the base of both operative and restorative dentistry. Present-day techniques need not be time-consuming and are definitely proved not to be of questionable value.

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Pasadena, Calif.

AMERICAN DENTAL ASSOCIATION 100 YEARS 1859 · 1959

# VELOPHARYNGEAL FUNCTION AND CLEFT PALATE PROSTHESES

ALI ARAM, D.M.D.,* AND J. DANIEL SUBTELNY, D.D.S.*
*Eastman Dental Dispensary, Rochester, N. Y.*

INTERESTED, WELL-INFORMED, AND RESOURCEFUL dentists have made remarkable contributions toward fulfilling the communicative needs of cleft palate individuals. This has been accomplished by the construction and placement of prosthetic appliances. Techniques and designs for prosthetic construction to improve speech potential have been described and discussed in dental literature.[1-4] Basically, these prosthetic "aids to speech" serve to obturate any opening or cleft of the palate and frequently carry an extension into the pharynx designed to improve or supplement velopharyngeal valving.

An understanding of normal velopharyngeal function and an appreciation of the consequences of abnormal function seem to be prerequisite to any meaningful discussion of data relating to cleft palate prosthesis. During speech, the soft palate normally elevates and retracts to contact pharyngeal structures which are constricting simultaneously. The synergistic behavior of the velar and pharyngeal musculature creates a sphincteric type of constriction, commonly called a velopharyngeal closure.

Adequate velopharyngeal closure prevents the passage of air from the oropharynx into the nasopharynx during function. Functional valving cannot be attained if a soft palate is short, limited in mobility, or cleft. As a consequence, air and sound energy are transmitted into and through the nasal cavity during speech. This results in an unpleasant nasal quality in speech and in a reduction of intraoral breath pressure. Because of this, some speech sounds cannot be produced and become distorted as well as weakened. A prosthesis with a pharyngeal extension may be constructed for such patients so that adequate valving for speech purposes can be developed.

The pharyngeal extension, usually constructed of acrylic resin, must conform to the dimension, shape, and position of the velopharyngeal opening which exists during function. It must be designed so that there is a close approximation of the functioning musculature around the acrylic resin section during speech and deglutition. Therefore, the proper positioning of the pharyngeal section is critical to prosthetic success.

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*Orthodontic Department.

Prosthetic failures, that is, those which do not improve speech potential appreciably, commonly result from pharyngeal sections which are inappropriate in size, shape, or placement. This study of normal velopharyngeal function was undertaken in an effort to acquire some useful information relative to the positioning of a prosthetic pharyngeal extension. Specifically, the approximate level of velopharyngeal closure was investigated. With the realization that speech aids are designed for children as well as adults, the possibility of changes in the level of closure, incident to growth, were evaluated.

## METHOD OF STUDY

For the purpose of this study, 90 subjects, ranging from 4 to 20 years in age, were studied. They were divided into six age groups: Group I (4-5 years of age), Group II (6-8 years of age), Group III (9-11 years of age), Group IV (12-14 years of age), Group V (15-17 years of age), and Group VI (18-20 years of age). Fifteen individuals were included in each age group. Three lateral cephalometric roentgenograms were made of each individual. Lateral headplates were secured with the teeth in occlusion, with the mandible at rest position, and with the subject phonating "oo" as in "food."

The cephalometric technique[5] permits the stabilization of the subject's head within a specially designed headholder. The position of the subject's head relative to the source of x-rays and the degree of magnification are controlled carefully. Thereby, the x-ray registrations are comparable from one functional position to the next and permit qualitative as well as quantitative analyses.

TABLE I. MEAN MEASUREMENTS IN DIFFERENT AGE GROUPS

| GROUP | AGE RANGE IN YEARS | SOFT PALATE MOVEMENT IN DEGREES | PALATAL PLANE TO MID-POINT OF CLOSURE (MM.) | ANTERIOR TUBERCLE OF ATLAS TO MID-POINT OF CLOSURE (MM.) |
|---|---|---|---|---|
| I | 4–5 | 44.83 ± 8.32 | −1.33 ± 2.42 | 2.97 ± 3.36 |
| II | 6–8 | 44.99 ± 8.01 | −0.07 ± 2.30 | 4.70 ± 2.85 |
| III | 9–11 | 51.37 ± 6.20 | 2.00 ± 2.49 | 6.50 ± 4.38 |
| IV | 12–14 | 55.93 ± 6.38 | 2.80 ± 2.77 | 6.47 ± 4.78 |
| V | 15–17 | 60.10 ± 9.01 | 3.03 ± 2.92 | 7.50 ± 5.25 |
| VI | 18–20 | 56.50 ± 5.06 | 2.78 ± 2.60 | 5.87 ± 4.21 |

The roentgenograms obtained while the subject was at "rest" and during the phonation of "oo" were studied and traced. In a few roentgenograms, where the entire configuration of the soft palate at rest was not clearly visible, a tracing of the headplate with the teeth in occlusion was made for the purpose of comparison and as a guide for outlining the soft palate and related structures. The two tracings of the same subject were superimposed on the palatal plane (a line drawn from the anterior nasal spine to the posterior nasal spine of the hard palate), and a composite tracing was made. From the composite tracing, various linear and angular measurements were made.

SOFT PALATE MOVEMENT

The position of the soft palate at rest was defined by a line drawn from the posterior nasal spine of the hard palate to the tip of the uvula. The position of the soft palate during phonation was defined by a line drawn from the posterior nasal spine to the mid-point of velopharyngeal closure. The degree of movement was determined by measuring the angle formed between these two lines. Means for the degree of soft palate movement from rest to closure were established for each age group.

In all instances, the soft palate moved in an upward and backward direction to create a closure (Fig. 1). The degree of velar movement from rest to closure was found to increase with increment in age (Table I). In other words, the soft palate moved a greater amount in older age groups in order to contact the superior

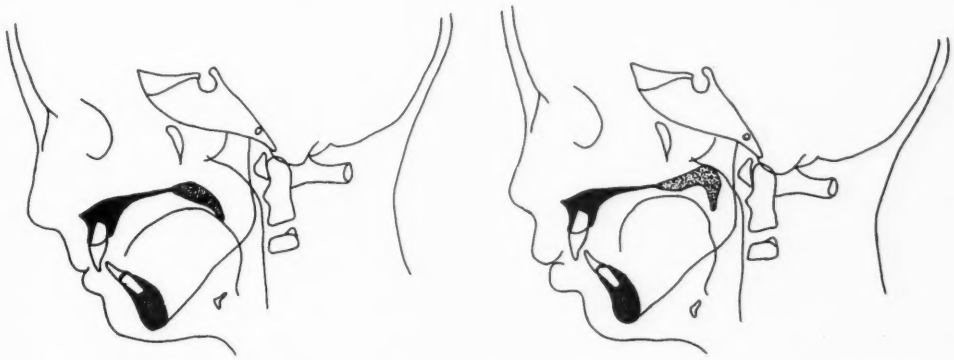

Fig. 1.—Soft palate at rest and during velopharyngeal closure. Tracings of cephalometric roentgenograms depict the upward and backward movement of the soft palate (stippled area) during phonation. Left, rest. Right, closure; phonation "oo."

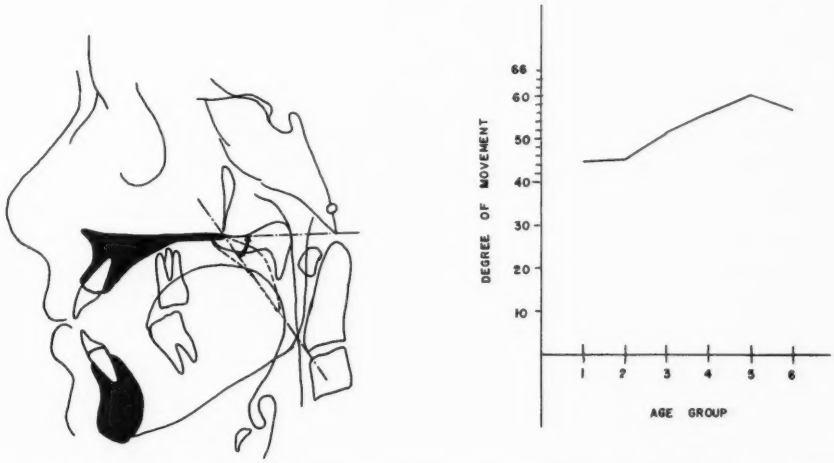


Fig. 2.—A tracing of a cephalometric roentgenogram illustrates the method of measuring the degree of soft palate movement, rest to closure. The graph shows the average degree of movement for each age group.

and/or the posterior pharyngeal wall. The mean established for the degree of movement was the same for the first two age groups (4-8 years of age). Thereafter, the degree of soft palate movement increased continuously until seventeen years of age. In the last group (18-20 years of age), the movement of the soft palate decreased somewhat to the approximate degree of movement defined for the 12- to 14-year age group (Fig. 2).

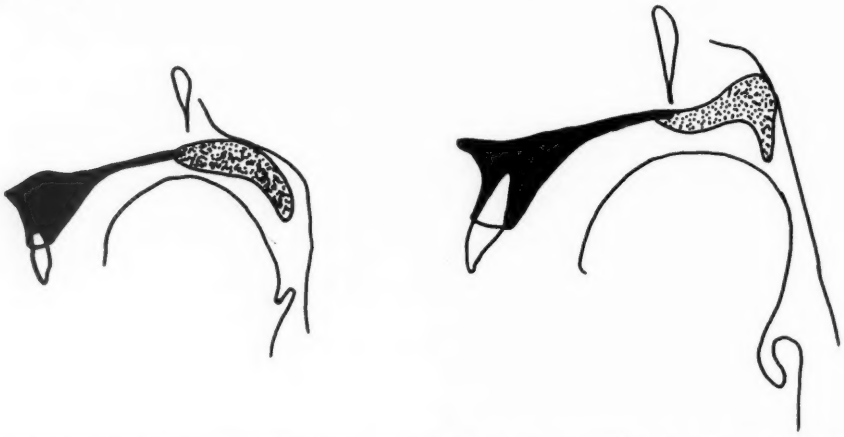

**Fig. 3.—Soft palate at closure. The site of closure during phonation is different at different age levels.**

SITE AND SPAN OF CLOSURE

Examination of the cephalometric headplates obtained during the phonation of "oo" revealed that there was a change in the site of velopharyngeal closure relative to age. The soft palate most frequently approximated the superior and/or the superior-posterior aspects of the nasopharynx in the younger age groups. In the older age groups, the soft palate almost always contacted the posterior pharyngeal wall during phonation (Fig. 3). The transition was particularly noticeable in the 9- to 11-year age group.

It seems logical that the site of closure should change with increment in age. At an early age, the soft palate is closer to the base of the cranium and the underlying soft tissue forming the roof of the nasopharynx.[6] At the same time, a mass of adenoid tissue is frequently present. This tissue serves effectively to bring the roof of the nasopharynx closer to the level of the soft palate. Therefore, it would seem that the soft palate could approximate the superior and/or the superior-posterior aspect of the nasopharynx with a lesser degree of elevation at an early age. In the older age groups, adenoid tissue is no longer evident. There is an increased vertical distance between the hard palate and the base of the cranium, and the soft palate is observed to assume a more nearly vertical relationship to the base of the skull. These factors increase the dimensions through which velar movement occurs. As a result, the soft palate in function approximates the posterior pharyngeal wall rather than the superior-posterior aspect of the nasopharynx.

Not only did the site of velopharyngeal closure change with increment of age, but the amount of velar tissue effecting the closure was also observed to change with

age. In order to quantitate this observation, the linear span of the soft palate tissue contacting pharyngeal tissue during phonation was measured. The vertical span of soft palate tissue effecting the velopharyngeal closure in the mid-sagittal plane of the head was found to decrease from an average of 8.6 mm. in the first age group to 4.4 mm. in the last age group. As the figures indicate, the reduction in average span or vertical extent of closure represents only 4 mm. However, the significant observation is that this change is almost equal to a 50 per cent reduction in vertical extent of closure.

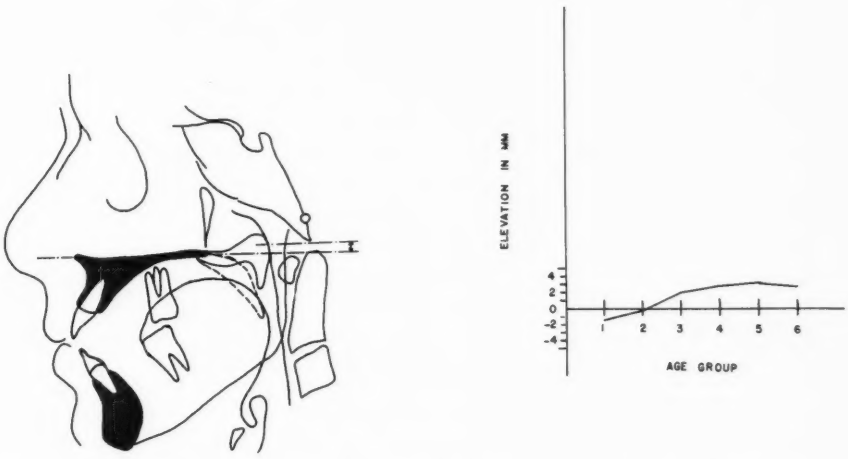


Fig. 4.—A tracing of a cephalometric roentgenogram illustrates the method of measuring in millimeters from the palatal plane to the mid-point of closure. The graph shows the average position of the mid-point of closure to the palatal plane for each age group.

The minimum span of soft tissue contact was 1 mm., and this was observed in only 3 of the 90 subjects studied. Point contact between velum and pharynx was not found during velopharyngeal closure in any of the subjects studied.

It has been reported that during functional valving of the velopharyngeal port, the middle third of the soft palate contacts the pharyngeal wall.[7] This statement is supported by the present data and appears to be especially applicable to the younger age groups. However, in the older age groups, it seemed that the more distal portion of the middle third of the velum was most functional in effecting the closure. This apparent change is compatible with the decrease in the span of closure, both of which could result from increased pharyngeal dimensions incident with growth.

Normally, the uvula of the soft palate does not contribute appreciably to effecting a velopharyngeal closure during speech function. On lateral cephalometric roentgenograms, the uvula generally is not found to be in contact with pharyngeal tissues during function (Fig. 3).

Incident with growth, the changes in site of closure have been described relative to the pharynx. The fact that the pharynx itself goes through morphologic alterations suggests that the level or site of closure might well be evaluated in reference to the palatal plane. In order to do this, the vertical distance from the palatal plane to the mid-point of closure was measured (Fig. 4).

The level of velopharyngeal closure was found to be closely related to the palatal plane. On the average, the mid-point of velopharyngeal closure was slightly below the level of the palatal plane from 4 to 8 years of age. Thereafter, it was consistently above the level of the palatal plane. After 9 years of age, the mean established for the mid-point of closure in reference to the palatal plane was not only consistently above the level of the palatal plane, but was found to be comparatively stable as well. The means ranged from 2 mm. in the 9- to 11-year age group to 3 mm. in the older age groups (Table I). From these measurements, it can be postulated that a mature level of velopharyngeal closure, in relation to the palatal plane, is attained by approximately 12 years of age and that little change occurs in the level of function thereafter.

The level of velopharyngeal function is related frequently to the anterior tubercle of the first cervical vertebra. For this reason, the vertical distance between the mid-point of closure and the most prominent point of the anterior tubercle of the atlas was measured for each age group. The resulting measurements showed much more variability than was observed when closure was related to the palatal plane. In all age groups, the means revealed that the mid-point of closure was always above the level of the anterior tubercle of the atlas (Fig. 7). In addition, the vertical distance between the mid-point of closure and the most prominent point of the anterior tubercle of the first cervical vertebra was found to increase with age.

There are several reasons why velopharyngeal function should be considered in reference to the palatal plane. Primarily, the soft palate is a contiguous structure with some of its muscular components inserting as well as taking origin on the hard palate and its attached aponeurosis. In addition, some muscular components of the velum insert into the pharynx. Because of this anatomic and physiologic inter-relationship, the myodynamics of the velopharyngeal region can best be considered in reference to the palatal plane. To a great extent, these factors may account for the finding that there is less variability in defining the level of velopharyngeal closure when it is located in reference to the palatal plane. As a corollary, the anterior tubercle of the atlas drops in vertical relationship to the base of the skull at a faster rate than does the hard palate with increment in age.[8] This may account for the increase in vertical distance between the level of velopharyngeal closure and the tubercle of the atlas.

## CLINICAL IMPLICATIONS

These findings may be helpful in diagnosis and treatment planning for cleft palate individuals. They provide some quantitative information relative to the normal function of the soft palate and the relationship of this tissue to contiguous structures. Such information appears to have considerable clinical application in regard to the construction of cleft palate prostheses. Specifically, the findings relate directly to the functional level for the placement of the pharyngeal section of the prostheses.

Although the average degree of soft palate movement during phonation increased with increment in age, the mid-point of the velopharyngeal closure was closely related to the level of the hard palate. On the average, it was slightly below

Fig. 5.—A tracing of a cephalometric roentgenogram of an individual with an adequate speech appliance, phonating "oo." The prosthesis passes through an unoperated cleft of the palate. The pharyngeal section is above the palatal plane. Note that the pharyngeal section contacts the posterior pharyngeal wall above the level of a Passavant's pad.

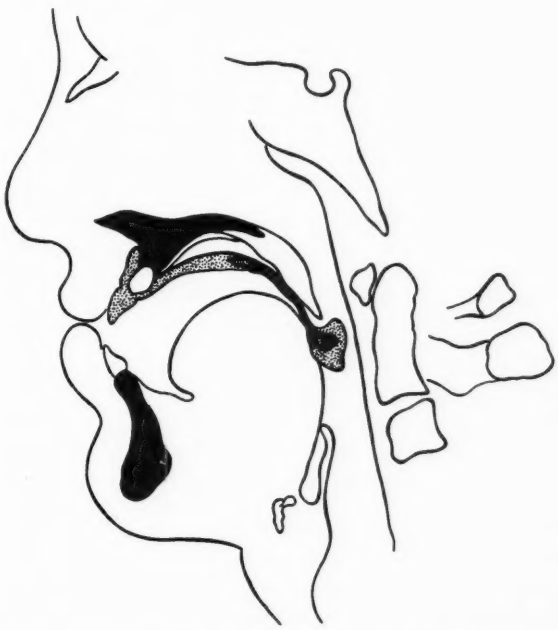

Fig. 6.—A tracing of a mid-sagittal laminagraph of an individual with an inadequate speech aid phonating "oo." The pharyngeal section does not aid velopharyngeal function during phonation. Air and sound energy can pass readily from the oral pharynx into the nasopharynx during function.

the level of the hard palate until 8 years of age and, thereafter, consistently above it. This normative data indicates that the projected level of the hard palate should serve advantageously as a "guidepost" in approximating the region of muscular function during speech. If the pharyngeal extension of the prosthesis is above the palatal plane in the region of muscular function, it can serve best as an adequate speech aid (Fig. 5). If it is much below this level, it may obturate the cleft, but remain ineffectual in assisting velopharyngeal function (Fig. 6).

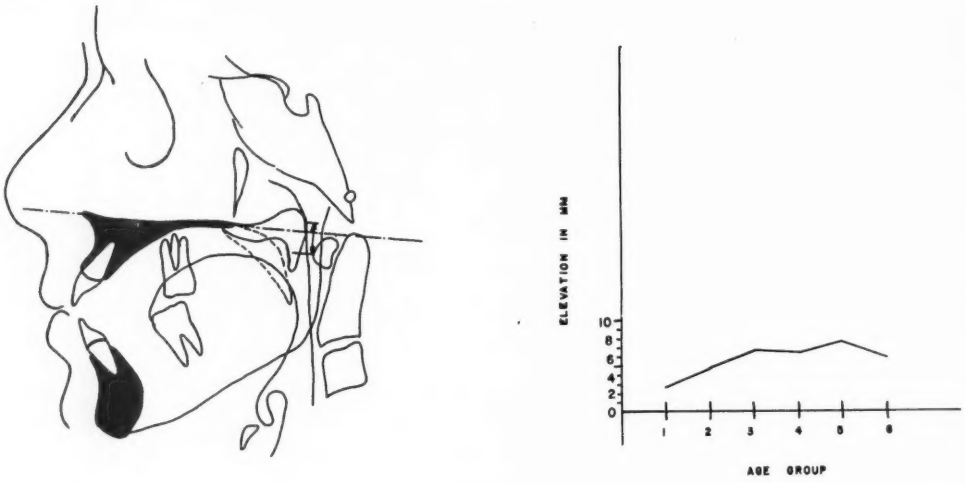


Fig. 7.—The average level of the mid-point of velopharyngeal closure relative to the anterior tubercle of the first cervical vertebra.

Many dentists have attempted to approximate pharyngeal tissue overlying the anterior tubercle of the first cervical vertebra on the basis that this area was that of maximum pharyngeal constriction.[2] The present data show that this would be a poor landmark for guidance in the construction and placement of the pharyngeal sections (Fig. 7). The pharyngeal extension should be placed as nearly as possible within the region of muscle function, i.e., the nasopharynx. If the soft palate is completely cleft, the prosthesis can easily extend through the opening of the cleft to the desired level (Fig. 5). If the soft palate is intact, or surgically closed, but short, the extension should follow the oral contour of the resting soft palate and then project upward and backward to reach the desired level within the nasopharynx (Fig. 8).

The pharyngeal section must be properly designed once the desired level is reached. It must be recognized that individual asymmetries in pharyngeal function exist. There are differences in the degree and location of pharyngeal movement as well as in velar activity which may make it necessary to modify the shape and placement of the pharyngeal section. However, functional valving must be attained on the anterior, posterior, and lateral aspects of the pharyngeal section. The acrylic resin section must contact the posterior pharyngeal wall and be contacted by the muscles of the lateral aspects of the nasopharynx as well as the soft palate during function. The lateral walls of the nasopharynx usually move medially during velo-

pharyngeal function. If the acrylic resin section is not adequate in its lateral extension, the muscles of the lateral walls of the nasopharynx will not contact it, and an opening between the oral and nasopharynx will exist. This will defeat the purpose of the prosthesis. The dentist must examine the lateral extension of the pharyngeal prosthesis carefully, for it is overlooked frequently, and it is a potential source of failure.

On the lateral cephalometric roentgenograms, it was observed that the span of soft palate tissue contacting the posterior pharyngeal wall during velopharyngeal closure was not great. Thus, it would seem that the pharyngeal section of a prosthesis would not have to contact the posterior pharyngeal wall over a very large vertical area. In older age groups, when the soft palate normally contacts the posterior pharyngeal wall, the pharyngeal prosthesis does not necessarily have to extend all the way to the superior aspect of the nasopharynx. This consideration

Fig. 8.—A tracing of a cephalometric roentgenogram on an individual with a surgically repaired cleft palate. The prosthetic extension first projects downward to accommodate the soft palate at rest. It then projects toward the cranium to carry the pharyngeal section into the nasopharyngeal region. The subject was phonating "oo" during the roentgenographic procedure.

could advantageously aid in preserving the health of the supporting structures of the dentition. It seems important that the dentist should strive to keep the mass of the pharyngeal section to an absolute minimum in size and yet sufficiently bulky to function properly. For stability, the dentist must clasp dental units for the anchorage of a prosthesis which extends posteriorly into the nasopharynx. Unnecessary bulk, in addition to the muscular forces exerted upon the pharyngeal section, will increase "leverage" stresses placed upon the clasped teeth. Eventually, the supporting structures of the teeth may be damaged. With an unfavorable alteration in the supporting structures of the teeth utilized for anchorage, the stability of the "speech aid" may be lost.

The prosthodontist is called upon frequently to construct a "speech aid" when all other therapeutic procedures have failed. In many instances, it remains the only hope for an adequate speech rehabilitation of an individual with a cleft of the palate. It should behoove the dentist to use all possible measures to construct an adequate speech aid. This can be accomplished only with a careful diagnosis and careful appliance construction, strengthened with the knowledge of the correct position of the individual parts for proper function. The normative data presented may be helpful in indicating the proper position for the pharyngeal section of a speech appliance.

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800 Main St., E.
Rochester 8, N. Y.

# MAXILLOFACIAL PROSTHESIS AND ITS ROLE AS A HEALING ART

DUNI C. MIGLANI, B.Sc., D.D.S., M.S.D.,* AND JOE B. DRANE, D.D.S.**
*University of Texas Dental Branch, Houston, Texas*

DEFORMITIES OF THE ORAL and facial structures may be classified under congenital deformities, such as cleft palate and harelip, and the acquired deformities, such as war injuries, accidental injuries, and radical disfiguring surgery which is often necessary in the treatment of malignant lesions of the head.

Patients with these deformities present various problems, both physical and psychological, and should be handled with the utmost care. Each patient's problem is different, and, therefore, each should be treated on an individual basis.

Although much difficult but excellent work has been performed to correct these conditions in recent years, it is still a regrettable fact that many persons still suffer from the effects of these deformities and further are unaware that much can be done for them either surgically, by prosthetic means, or by a combination of these methods. Surgical repair is preferred for many of these patients. There are conditions, however, which would contraindicate plastic surgery, such as the age of the patient, the general health of the patient, the size and extent of the deformity, and the condition of the tissues because of the poor blood supply following radiation. Furthermore, many of these patients, because of their recent illness and the expenses which they have incurred, may not be in a position to afford the time or the cost of plastic surgery. Therefore, the only treatment left for these patients is a maxillofacial prosthetic appliance.

Maxillofacial prosthesis is a branch of medical and dental science which aims to protect and, directly or indirectly, restore structures that are injured or lost by congenital or acquired means beyond the limits of a usual prosthesis which restores the teeth and the alveolar ridges. The field of maxillofacial prosthesis is not new. It dates back to the time before recorded history, but its recognition as a science took place during the time of the first world war. It has progressed so that, with the new materials which are presently available, it is possible to make lifelike individual skin matching prostheses.

## INDICATIONS FOR MAXILLOFACIAL PROSTHESIS

There are numerous indications for maxillofacial prosthesis. The chief objectives are to construct appliances which will aid in surgery, will partly or wholly restore function, and will improve esthetics and speech, thereby benefiting the morale of patients.

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*Teaching Fellow, University of Texas Dental Branch, and Resident, M. D. Anderson Hospital.

**Associate Professor, Department Maxillofacial Somato-Prosthesis, University of Texas Dental Branch.

The number and type of potential maxillofacial patients is very large. In the United States alone, there are about 500,000 to 750,000 people who are wearing artificial eyes. The incidence of congenital cleft palate is one in approximately 800 live births.

In a large hospital, there is a constant need for surgical splints, stents, and other appliances which demand the services of a maxillofacial prosthodontist. The need of a maxillofacial prosthodontist on the cleft palate team and on the cancer service cannot be overemphasized. It is often necessary to perform radical surgery for cancer patients in order to save the patient's life. These patients are sometimes left with deformities involving the partial or complete loss of an ear, nose, eye, palate, jawbone, cheek, or a combination of these structures. The deformities leave the patient not only physically handicapped, but lead to serious psychologic problems. Cleft palate and cancer patients require corrections of these deformities so that they may partially regain lost function and live without undue embarrassment. The best results with these patients can be achieved usually if the replacement can be inserted and adjusted in the patient's mouth immediately after the operation. During the first few days after the operation the muscle pull is strongest, and if not corrected, it may disarrange the position of bone fragments and tissues.

In the year 1955-1956, the Department of Maxillofacial Prosthesis at the University of Texas Dental Branch scheduled 616 patient visits, of which 71 were new patients. One hundred and twenty-three intraoral prostheses were constructed which included temporary, immediate temporary, or permanent obturators, stents,

TABLE I. THE TOTAL NUMBER OF PATIENTS TREATED BY THE MAXILLOFACIAL DEPARTMENT DENTAL BRANCH, UNIVERSITY OF TEXAS

| | 1955-1956 | 1956-1957 |
|---|---|---|
| I. Patient visits | 616 | 909 |
| (a) New patients | 71 | 103 |
| (b) Return visits | 545 | 806 |
| II. Type of prostheses | | |
| A. Intraoral | 123 | 164 |
| (i) Obturators | 67 | 60 |
| (a) Immediate temporary | 0 | 21 |
| (b) Temporary | 35 | 24 |
| (c) Permanent | 32 | 15 |
| (ii) *Complete dentures | 42 | 85 |
| (iii) *Partial dentures | 5 | 7 |
| (iv) Splints | 0 | 2 |
| (v) **Stents | 3 | 4 |
| (vi) Interocclusal splints | 0 | 2 |
| (vii) Cleft palate appliances | 1 | 2 |
| (viii) Resection appliances | 5 | 2 |
| B. Extraoral or facial prostheses | 48 | 45 |
| (i) Noses | 15 | 14 |
| (ii) Ears | 9 | 7 |
| (iii) Eyes | 14 | 15 |
| (iv) Combinations | 7 | 9 |
| (v) Somato | 3 | 0 |

*These partial or complete denture patients are of a complex nature with mutilated or deformed arches.

**Stents may be extraoral or intraoral.

splints, resection appliances, cleft palate appliances, interocclusal splints, and 48 extraoral prostheses for the eye, ear, nose, cheek, or combinations thereof. In the year 1956-1957, 164 intraoral and 45 extraoral prostheses were fabricated (Table I).

Fig. 1.

Fig. 2.

Fig. 1.—A maxillary resection for which an immediate temporary obturator was constructed.
Fig. 2.—The immediate temporary obturator in place.

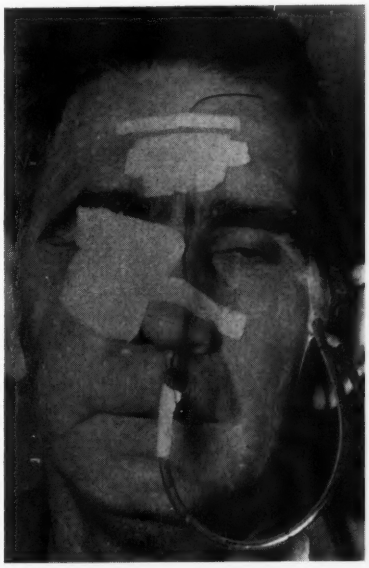


Fig. 3.—An edentulous patient with a maxillary resection and with a nasal feeding tube in position.

## TYPES OF MAXILLOFACIAL PROSTHESES

No effort has been made in this article to describe in detail the technique of constructing these prostheses, but some representative cases have been chosen to illustrate the different types of restorations and the results obtained.

Figs. 1 and 2 show a maxillary resection for which an *immediate temporary obturator* was inserted at the time of surgery. Until July, 1956, no attempt was

made to construct such immediate temporary obturators. Cancer patients with maxillary resections had to wait for a period of 8 to 14 days before the obturators could be inserted. This meant that these patients had to be fed during all of that time through nasal tubes. They had the further inconvenience of not being able to speak with an intelligible voice (Fig. 3). Twenty-one immediate temporary obturators were constructed in the Department of Maxillofacial Prosthesis in the year 1957, and it is felt that these appliances were of tremendous importance to the patients undergoing maxillary resections. These appliances not only restore the functions of deglutition, speech, and the sense of taste but prevent the abnormal muscular actions which result from an attempt to speak normally under abnormal conditions and from an attempt to swallow, since deglutition is usually an auto-

Fig. 4.

Fig. 5.

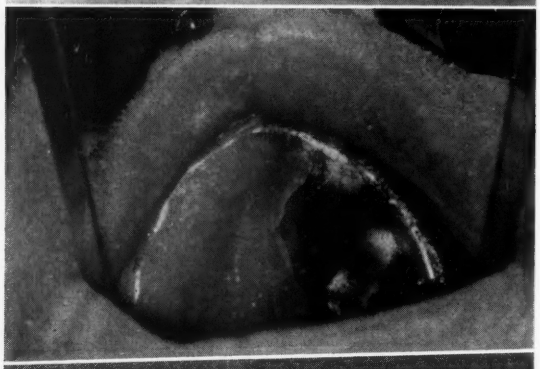


Fig. 6.

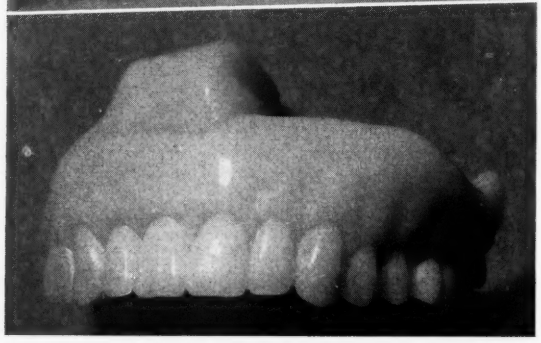


Fig. 4.—An edentulous patient with a maxillary resection.
Fig. 5.—A temporary obturator in place in the mouth of the patient seen in Fig. 4.
Fig. 6.—This permanent obturator is a part of the complete upper denture.

matic and involuntary act. They act as stents to keep the surgical packs and skin grafts in position and promote faster healing of the wounds. Bleeding is held to a minimum because of the pressure of these obturators on the tissues. There is only one prerequisite for the construction of immediate temporary obturators. The patient should be dentulous, and some abutment teeth should be present for clasping.

The immediate temporary obturator cannot be used successfully for completely edentulous patients who need maxillary resections (Fig. 4). Temporary obturators are constructed for these patients after a waiting period of ten days from the time of surgery (Fig. 5). After the healing of the wound is complete, the temporary obturator is replaced by a permanent obturator. The only difference between the temporary and permanent obturator is that teeth have been incorporated in the prosthesis (Fig. 6).

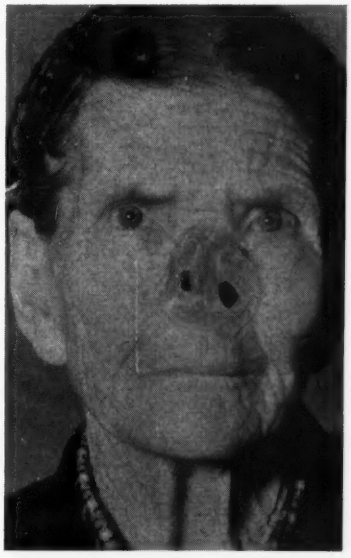


Fig. 7.—This stent is used to hold a radioactive substance and to keep it in contact with a recurrent malignant lesion of the nose.

## STENTS

A stent is an appliance or mold constructed so as to hold a skin or mucous membrane graft in place. The stent shown in Fig. 7 was constructed to carry a radioactive substance and to keep it in contact with a recurrent malignant lesion of the nose. This is one of the numerous indications for a stent.

## RESECTION APPLIANCE

It is sometimes necessary to resect the mandible in patients undergoing surgery for the removal of tumors of the lower jaw. This results in many problems, the principal ones being esthetics and difficulty in mastication. The relationship of the remaining portion of the mandible to the maxillae is disturbed because the remaining fragment turns inward and backward. A resection appliance is indi-

cated for these patients to help keep the lower jaw in its proper relationship to the upper jaw and helps to restore function and facial symmetry (Fig. 8). A partial resection of the mandible may require that the lost portion of the mandible be replaced by an internal plastic prosthesis (Figs. 9 and 10). This procedure is necessary only to achieve maximum cosmetic and functional results.

Fig. 8.

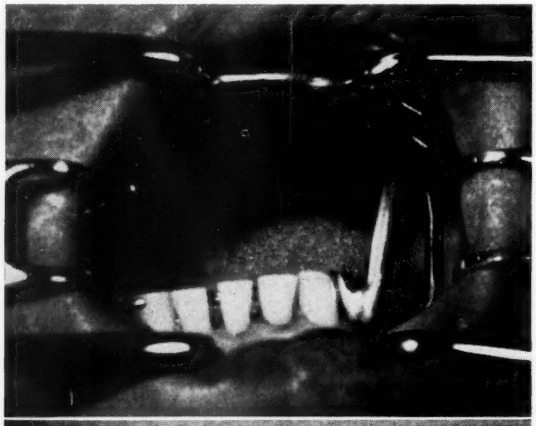


Fig. 9.

Fig. 10.

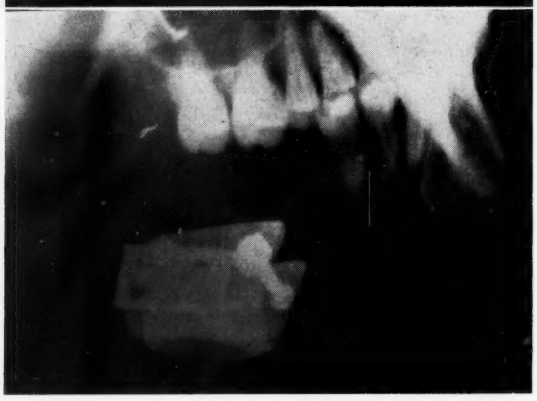


**Fig. 8.—This resection appliance is used to maintain the position of the remaining part of the mandible.**

**Fig. 9.—An internal appliance which was used for prosthetic repair following the resection of the mandible.**

**Fig. 10.—A roentgenogram showing the appliance (Fig. 9) in position.**

TRACTION APPLIANCE FOR TRISMUS

Trismus or closure of the jaw is one of the problems encountered in patients with oral and facial lesions. Among the various means used to alleviate this condition, best results have been obtained by a simple and nonexpensive appliance which utilizes traction by means of rubber bands (Fig. 11).

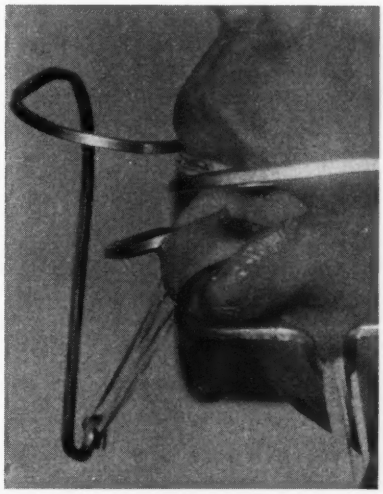
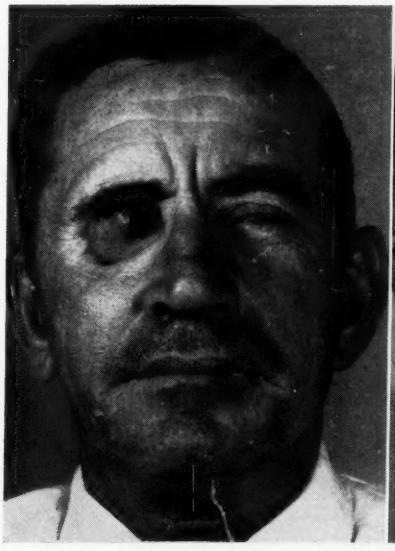


Fig. 11.—An interocclusal splint to provide traction is used to treat trismus.

Fig. 12.



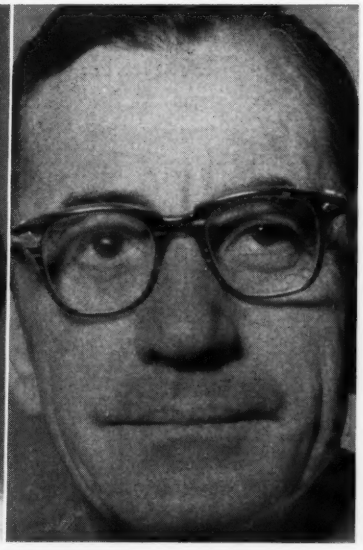


Fig. 13.

Fig. 12.—A patient with an exenteration of the eye.
Fig. 13.—A facial prosthesis for an eye is in position.

EXTRAORAL PROSTHESIS

The scope and indications for a facial or extraoral prosthesis have already been discussed. These may be for the eye, ear, nose, or combinations thereof. Fig. 12 is an example in which the exenteration of the eye was necessary because of a malignancy, and Fig. 13 shows the prosthesis in position and the result obtained. Figs. 14, 15, and 16 show a deformity around the nose and the repair as effected by prosthetic means. Glasses are a very good means for securing these facial prostheses in position. Sometimes certain surgical adhesives are necessary. A facial prosthesis for an ear is seen in Figs. 17 and 18. A combined facial prosthesis in which the greater part of both buccal sulci, the lip, and the teeth were lost is shown in Figs.

Fig. 14.

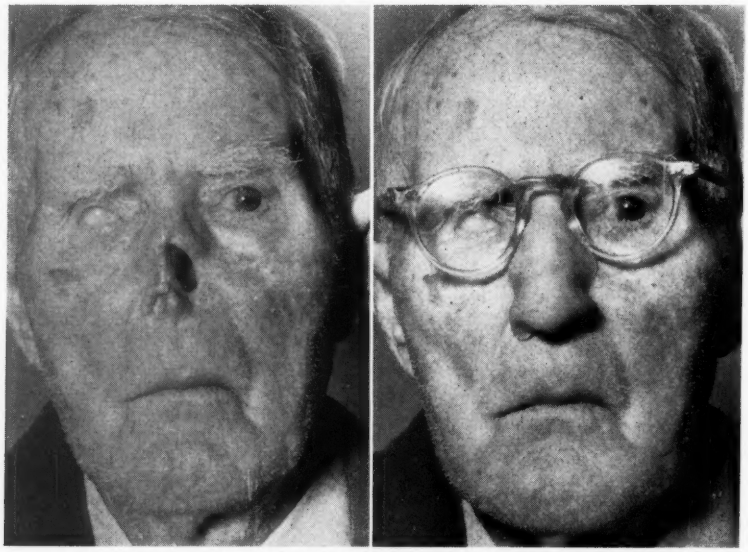


Fig. 15.

Fig. 14.—A deformity around the nose due to the surgical removal of a malignant lesion.
Fig. 15.—The prosthesis is retained by the glasses.

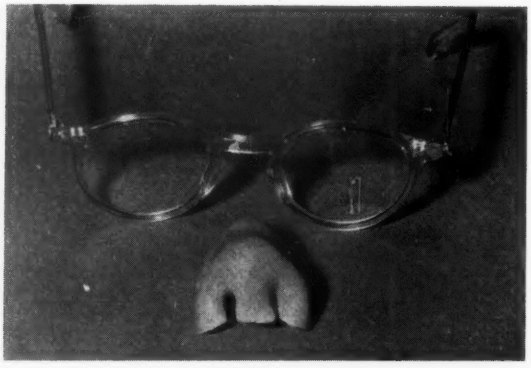


Fig. 16.—The nose prosthesis and the glasses.

Fig. 17. Fig. 18.

Fig. 17.—The deformity of an ear.
Fig. 18.—The ear prosthesis in position.

Fig. 19.

Fig. 20.

Fig. 19.—A deformity around the face, the lip, and the major part of the cheek. Both buccal sulci and the teeth are missing.
Fig. 20.—The complete dentures are in place.

19, 20, and 21. The teeth were replaced by upper and lower dentures over which the facial prosthesis was fabricated to replace the cheeks and lip. Buttons were incorporated on the buccal acrylic resin surface of the dentures, to which the external prosthesis was fastened. The facial prosthesis in turn was secured in position by glasses. A very remarkable esthetic and functional result was obtained.

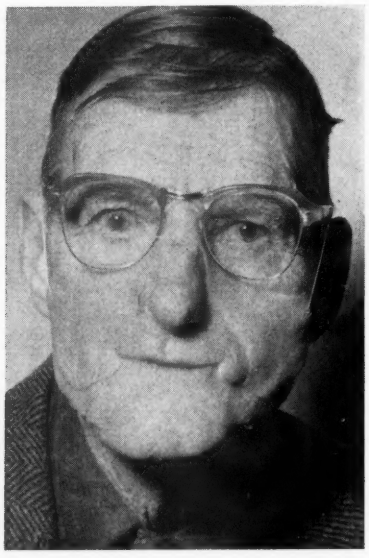


Fig. 21.—The facial prosthesis is in position over the dentures and retained by the glasses.

SUMMARY

The application of maxillofacial prosthesis has been discussed with examples to illustrate this highly specialized field of prosthetic dentistry. Oral and facial deformities which may be either acquired or congenital are seen in a large segment of the population. These unfortunate persons require the services of a maxillofacial prosthodontist.

Every dentist with a little training and *interest* is fully qualified to undertake this type of work and help the afflicted by replacing anatomic deficiencies, restoring physiologic functions, correcting impaired speech, improving esthetics, and, in so doing, building up the patient's morale.

The field of maxillofacial somatoprosthesis has been, until recently, an unheralded section of the prosthodontic service in dentistry. It is a sincere hope that more institutions will provide this type of service and that more dentists will take an interest and realize the importance of this branch of dentistry as a healing art.

The authors extend their sincere appreciation and thanks to Dr. Heinz O. Beck, Head of the Restorative Dentistry Department of the University of Texas Dental Branch, for his guidance in the preparation of this article.

The illustrations used in this article were provided by the Medical Illustrations Department for which thanks are due to Mr. Lawrence Binder and Miss Fern Fetters.

P. O. Box 20068, Houston 25, Texas

## SEVENTH ANNUAL ESSAY CONTEST

SPONSORED BY

THE AMERICAN DENTURE SOCIETY

Prizes will be awarded to the two senior dental students who submit the best essays on some phase of prosthetic dentistry in the seventh annual essay contest sponsored by The American Denture Society. The purpose of the contest is to stimulate technical writing by dental students.

The first prize is Five Hundred Dollars ($500.00) and the second prize is Three Hundred Dollars ($300.00).

RULES

1. The contest is open to all senior dental students of the United States and Canada.
2. Only two essays may be submitted from any one dental college. (It is recommended that each dental college conduct its own contest to determine the two best essays submitted by members of its senior class.)
3. Essays are to be on some phase of prosthetic dentistry and limited to a maximum of 3,000 words. The following topics are suggested:
   (a) Centric Relation and the Interocclusal Distance,
   (b) Registration of Mandibular Movements in the Construction of Complete Dentures,
   (c) Esthetics,
   (d) Diagnosis and Treatment for a Patient Requiring Unusual Prosthetic Services.
4. Essays must be worthy of publication in the JOURNAL OF PROSTHETIC DENTISTRY and must be prepared in a form which is satisfactory to the requirements of that JOURNAL.
5. The original essay and one copy must be submitted for the use of the judges.
6. Essays must be typewritten, double spaced, on a good grade of white bond paper 8½ by 11 inches. Paragraphs must be indicated clearly by indentations, and generous margins must be allowed on each page.
7. Illustrations must conform to the standards of the JOURNAL OF PROSTHETIC DENTISTY, if they are used. Only good glossy black and white photographic prints, or drawings in India ink may be used. Each illustration should be mounted on a separate sheet of paper with the figure number and the legend typed on the paper beneath the illustration.
8. The form and punctuation of references must conform to the style used in the JOURNAL OF PROSTHETIC DENTISTRY. The references must be keyed to the text material.
9. The permanent address of the author must be at the end of the reference page.
10. The student has a free range in the choice of topics within the broad interpretation of prosthetic dentistry.
11. Essays will be judged on the basis of subject matter, neatness, composition, spelling, illustrations, charts and tables, number and accuracy of references, continuity of thought, and length of the essay.
12. The judges of the contest are members of a committee of The American Denture Society. The decision of the judges is final.
13. Essays are to become the property of The American Denture Society. None will be returned.
14. All essays submitted to the contest shall be clearly marked "Contest Essay" and shall be accompanied by a letter from the professor of prosthetic dentistry and/or the dean of the dental college from which they originate. This provision is to assure the authenticity of all essays entered in the contest.
15. Essays must be postmarked on or before July 15, 1959 and sent to:

    Dr. Victor L. Steffel
    Secretary, The American Denture Society
    College of Dentistry, The Ohio State University
    Columbus 10, Ohio

# *NEWS AND NOTES*

## MEETINGS

American Denture Society, Congress Hotel, Chicago, Ill., Feb. 6 and 7, 1959.

American Academy of Crown and Bridge Prosthodontics, Conrad-Hilton Hotel, Chicago, Ill., Feb. 7 and 8, 1959.

American Academy of Restorative Dentistry, Conrad-Hilton Hotel, Chicago, Ill., Feb. 7 and 8, 1959.

Southeastern Academy of Prosthodontics, Atlanta Biltmore Hotel, Atlanta, Ga., March 13 to 15, 1959.

Academy of Denture Prosthetics, Sheraton-Seelback Hotel, Louisville, Ky., April 12 to 17, 1959.

American Association for Cleft Palate Rehabilitation, Sheraton Hotel, Philadelphia, Pa., April 30 to May 2, 1959.

American Dental Society of Europe, Stockholm, Sweden, July 7 to 10, 1959.

## THE AMERICAN BOARD OF PROSTHODONTICS

By authorization of the Council on Dental Education, the scope of the American Board of Prosthodontics has been enlarged to examine candidates whose background and practice are principally in the field of fixed partial denture prosthesis. Oral and written examinations will cover all phases of prosthodontics, but the candidate may elect the clinical examination in either fixed partial denture prosthesis or complete dentures, according to his background.

In order to apply, a candidate should have the equivalent of two years of graduate, residency, or postgraduate preparation in the field. Teaching in a Dental School will be evaluated on an individual basis as partially fulfilling the requirements. At least five years of practice including formal graduate training is a minimum. Ten years of practice is required of those who have had no graduate training but, by experience and reputation, have established themselves in the field of fixed denture prosthesis.

The next examination will be held at Northwestern University, School of Dentistry, Chicago, Ill., Aug. 31 through Sept. 5, 1959.

Applications may be secured from the secretary: Dr. Charles H. Jamieson, 563 David Whitney Bldg., Detroit 26, Mich.

## ANNOUNCEMENTS

Reprints of the "Glossary of Prosthodontic Terms" may be obtained by writing to Glossary Reprints, 400 Starks Bldg., Louisville, Ky. The price is fifty cents per copy. Please make your check or money order payable to Glossary Reprints and enclose with your order.

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The headquarters of the American Association of Dental Schools is now located at 838-840 North Lake Shore Drive, Chicago, Ill. Mr. Reginald H. Sullens, of Chicago, formerly associate secretary of the Council on Dental Education of the American Dental Association, is the new executive secretary of the American Association of Dental Schools. The announcement of these changes was made by Dr. Raymond J. Nagle, dean, College of Dentistry, New York University, and acting president of the American Association of Dental Schools.

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The Dental and Oral Surgery Service of the Mount Sinai Hospital in New York City announces that it is accepting applications for Internships and Residency for the calendar year beginning July, 1959.

For further information and application, write to Dr. Max Fuchs, Assistant Director, The Mount Sinai Hospital, 11 East 100th Street, New York 29, N. Y.

The Veterans Administration, Medical Teaching Group Hospital, Memphis, Tenn., announces that one rotating dental internship and one residency in Prosthodontics will be available for the year beginning July, 1959.

For further information and application, write to Chief of the Dental Service, Veterans Administration, Medical Teaching Group Hospital, Memphis, Tenn.

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Michael Reese Hospital announces the following course to be given immediately following the Chicago Midwinter Meeting:

The Medical Laboratory in Clinical Dentistry, Feb. 12 and 13, 1959.

For further information and the detailed program, write to Dental Department, Michael Reese Hospital, 29th Street and Ellis Ave., Chicago 16, Ill.

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The Department of Stomatology, Division of Graduate Studies, School of Medicine, Boston University, announces the following postgraduate courses:

Advanced Course in Periodontal Therapy, March 2 to 7, 1959.

Techniques in the General Practice of Dentistry, March 9 to 14, 1959.

Periodontal Therapy, March 16 to 27, 1959.

Tooth Preparation and Elastic Impression Material Techniques in Restorative Dentistry, March 30 to April 1, 1959.

Full Denture Prosthesis, April 6 to 15, 1959.

Occlusal Adjustment, April 27 to May 1, 1959.

Endodontics, May 11 to 15, 1959.

Periodontal Prosthesis, May 18 to 22, 1959.

Surgical Technics Employed in Periodontal Therapy, May 25 to 29, 1959.

Pulp Protection in Operative Dentistry, June 4 to 6, 1959.

Periodontal Pathology, June 8 to 12, 1959.

For further information, write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospital, 750 Harrison Ave., Boston 18, Mass.

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The University of Alabama, School of Dentistry, announces the following refresher courses:

Dental Assisting, Feb. 14 and 15, 1959.

A Practical Approach to the Full Denture Problem, Feb. 21 to 23, 1959.

Removable Orthodontic Appliance Construction, Feb. 28 to March 2, 1959.

Occlusal Adjustment, March 7 to 9, 1959.

For further information and application, write to Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., South, Birmingham, Ala.

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Northwestern University Dental School announces the following postgraduate courses:

Endodontics, Feb. 25 to 27, 1959.

Major Oral Surgery—A, March 2 to 13, 1959.

Intermediate Oral Surgery, March 16 to 20, 1959.

Complete Denture Procedures, March 30 to April 2, 1959.

Major Oral Surgery—B, April 6 to 10, 1959.

Prosthetic and Orthodontic Rehabilitation for the Cleft Palate Patient, April 6 and 7, 1959.

High Speed Instrumentation, April 15 and 16, 1959.

Pedodontics, April 15 and 16, 1959.

Use of Drugs in Dental Practice, April 29 to May 1, 1959.

Diagnosis, Roentgenography, and Treatment Planning, May 4 and 5, 1959.

Pedodontic Teachers' Conference, June 8 and 9, 1959.

For further information and application, write to Director of Dental Postgraduate Study, Northwestern University Dental School, 311 E. Chicago Ave., Chicago 11, Ill.

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The Ohio State University, College of Dentistry, announces the following postgraduate courses:

Complete Denture Prosthodontics, Feb. 16 to 20, 1959.
Partial Denture Prosthodontics, Feb. 23 to 27, 1959.
Endodontics, March 2 to 6, 1959.
Pedodontics, March 9 to 13, 1959.
Fifteenth Annual Post College Assembly, April 15 to 16, 1959.
General Anesthesia, April 20 to 24, 1959.
Dental Drugs in Action, May 1 and 2, 1959.
Periodontics, May 4 to 8, 1959.
For further information and application, write to Postgraduate Division, College of Dentistry, The Ohio State University, Columbus 10, Ohio.

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University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:
Mandibular Third Molar, Feb. 9 to 13, 1959.
Oral Diagnosis and Roentgenology, Feb. 16 to 20, 1959
Periodontal Prosthesis, Feb. 16 to 20, 1959.
Partial Dentures, Feb. 23 to 27, 1959.
Occluso-Rehabilitation, March 2 to 6, 1959.
Principles of Occlusion, March 4 to 6, 1959.
Oral Medicine, March 9 to 13, 1959.
Cephalometry, March 9 to 11, 1959.
Applied Anatomy, March 16 to 18, 1959.
Extraoral Tracers in Rehabilitation of Function, March 16 to 18, 1959.
Pulp Reactions, April 2 and 3, 1959.
Minor Tooth Movement, April 8 to 10, 1959.
Tenth Mid-Atlantic States Conference in Dentistry, April 12 to 17, 1959.
Endodontics, April 13 to 24, 1959.
Clinical Occlusion, April 20 to 24, 1959.
Complete Dentures, April 27 to May 1, 1959.
Newer Concepts in Oral Rehabilitation, May 4 to 8, 1959.
Refresher Course in Periodontal Therapy, May 9, 1959.
Advanced Periodontal Therapy, May 11 to 15, 1959.
Complete Denture Seminar, May 14, 1959.
Complete Denture Prosthesis, May 18 to 22, 1959.
The Use of High Speed Instruments and Equipment, May 20 and 21, 1959.
Immediate Root Resection, June 1 to 6, 1959.
Twin Wire Mechanism, June 1 to 5, 1959.
For further information and application, write to Director, Postgraduate Courses, School of Dentistry, University of Pennsylvania, 4001 Spruce St., Philadelphia 4, Pa.

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Western Reserve University, School of Dentistry, announces the following postgraduate course:
Psychodynamics and Practice Administration, March 30 through April 1, 1959.
For further information and application, write to Director of Postgraduate Education, School of Dentistry, Western Reserve University, Cleveland 6, Ohio.

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The New York University, College of Dentistry, announces the following postgraduate courses:
Refresher Course in Periodontics and Oral Medicine, Feb. 11 to April 22, 1959 (Wednesdays, 4:00 to 6:00 P.M.).
Periodontics and Oral Medicine in the Spanish Language, Feb. 23 to March 27, 1959.
For further information and application, write to Dr. Sidney Sorrin, Department of Periodontia and Oral Medicine, New York University, College of Dentistry, 421 First Ave., New York 10, N.Y.

Temple University, School of Dentistry, announces the following graduate and postgraduate courses:

Head and Neck Dissection, Feb. 4 through June 10, 1959.
Periodontal Prosthesis, Feb. 16 to 20, 1959.
Practice Administration, Feb. 28, 1959.
Time, Motion, and Speed, March 1 to 3, 1959.
Oral Medicine for General Practitioner, March 9 to 13, 1959.
Gnathology and Oral Rehabilitation, March 9 to 14, 1959.
Electronic Electrosurgery, March 20 and 21, 1959.
Full Denture Prosthesis, April 6 to 11, 1959.
Full Denture Prosthesis—Advanced, April 12 to 18, 1959.
Advanced Surgical Techniques in Periodontal Therapy, April 18 to 22, 1959.
Transographics in Full Mouth Restoration, May 4 to 9, 1959.
Fundamental Periodontics, June 1 to 5, 1959.
Immediate Root Resection, June 1 to 6, 1959.

For further information and application, write to Postgraduate Division, Temple University, School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

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Tufts University School of Dental Medicine announces the following postgraduate refresher courses:

Occlusal Equilibration, Feb. 9 to 11, 1959.
Local Anesthesia, Feb. 9 to 11, 1959.
Minor Oral Surgery, March 4 to April 22, 1959 (Wednesdays).
Occlusal Adjustment, March 30 to April 1, 1959.
Clinical Adjustment of the Occlusion, April 2 to 4, 1959.
Full Denture Implants, April 6 to 10, 1959.
A Special Participation Course in Periodontology, April 13 to 17, 1959.
Occluso-Rehabilitation I, April 20 to 24, 1959.
Oral Roentgenology, April 22, 1959.
Full Denture Prosthesis, June 1 to 5, 1959.
Clinical Dentistry for Children, June 15 and 16, 1959.

For further information and application, write to Director of Graduate and Postgraduate Studies, Tufts University, School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

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The Nomenclature Committee of the Academy of Denture Prosthetics plans to present recommendations for revision of the Glossary of Prosthodontic Terms (J. PROS. DEN. **6**:Appendix, March, 1956) to the Academy next April. For that reason, constructive suggestions are again invited. Revisions will involve the addition of terms not included in the original Glossary, deletion of certain obsolete or objectionable terms, and changes in definitions to clarify the meaning of some terms. It is particularly desired that suggestions for new or modified definitions include a proposed definition which is considered to describe clearly the term involved.

Communications should be addressed to the Chairman of the Nomenclature Committee, Dr. Carl O. Boucher, The Ohio State University, College of Dentistry, Columbus 10, Ohio.

# *READERS' ROUND TABLE*

October 17, 1958.
New York, N. Y.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

The following is in answer to the letter written by Dr. Harry Sicher, as printed by THE JOURNAL OF PROSTHETIC DENTISTRY [Readers' Round Table, J. PROS. DEN. **8**:899-900, 1958]. If, as stated by Dr. Sicher, the letter was "written in the interest of scientific truth . . . and, last but not least, in fairness to Dr. Jerome Schweitzer," it is indeed surprising that he did not permit me to read the letter prior to his sending it to the editor.

It would appear that Dr. Sicher was a bit over-zealous in going out of his way to explain how Harry Page tried to confuse his readers. Is Dr. Sicher in a position to conclude for the profession that "The main tenet of Transographics, namely, the 'split axis,' has been exploded by Trapozzano's article"? I object to Dr. Sicher's one example. I redrew the figure of Fick on white paper, and sent it to THE JOURNAL OF PROSTHETIC DENTISTRY glued to a cardboard background. The figure printed was not a photograph of the original (see Figs. 1 and 2) but

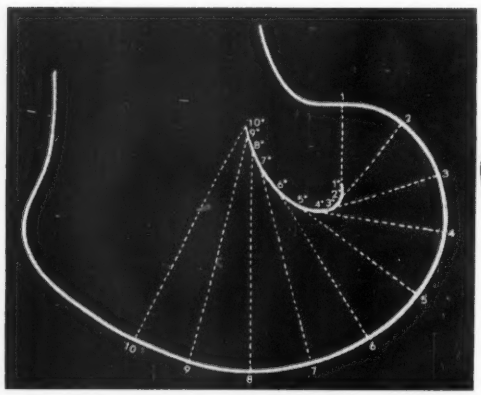

Fig. 1.—The original illustration (From Fisk).

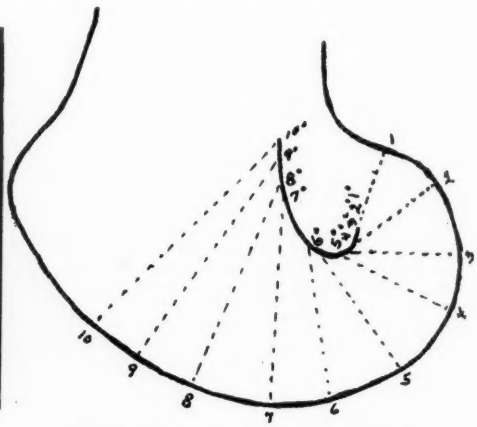

Fig. 2.—The copy properly oriented.

rather a drawing made by me of a femoral condyle, properly numbered both top and bottom, to facilitate reading of the numbers. It was inadvertently reversed by the JOURNAL, and then returned to me for proofreading. The error was overlooked by me, and so incorrectly printed. Harry Page had no connection in this matter. The caption beneath figure 8 stated, "A spiral joint (femoral condyle in profile) . . . (Redrawn from Fick, 1911.)" The figure was clearly defined in the caption beneath figure 8, allowing no room for intent "to confuse," but rather a simple description of the evolute curve which results from connecting the consecutive axis centers, as created by an irregular body, such as the condyle, or femor, when turning against its fossa. Page did not reverse "the outline of the femoral condyle so that it now resembles, superficially, a mandibular condyle." The drawing was made by me, and inadvertently reversed by the JOURNAL. As previously stated, the fault rests entirely with me for not having corrected the error prior to returning the proofs to the JOURNAL.

It is in the interest of scientific truth that the figure be correctly shown, but Dr. Sicher should limit his criticism to the facts at hand, rather than inject personal feelings in judging another man's intentions.

Sincerely yours,

JEROME M. SCHWEITZER, D.D.S.

*Apologies are in order:* Apparently an error in the orientation of an illustration in the article "The Transograph and Transographic Articulation" by Jerome M. Schweitzer, D.D.S. [J. PROS. DEN. **7**:595-621, 1957] has caused considerable concern to the readers as well as to the author of this article. This illustration was inverted unintentionally, and the error was mechanical in nature. It points up the necessity for *authors* to indicate clearly the "TOP" of each illustration rather than to depend upon the subject matter for orientation. This was not done on the illustration in question. I accept my share of responsibility along with the author for the error. I apologize to the author and any others who may have been hurt, misled, or confused by it.

CARL O. BOUCHER, Editor

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